

AD-A278 153



**U.S. Army Research Institute
for the Behavioral and Social Sciences**

Research Report 1660

MANPRINT Support of the Non-Line-of-Sight Fiber-Optic Guided Missile System

**William R. Sanders
U.S. Army Research Institute**

**DTIC
ELECTE
APR 13 1994
S G D**

94-11108



94 4 12 06 7

January 1994

Approved for public release; distribution is unlimited.

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction
of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Director

Technical review by

Kenneth Reynolds
Joan D. Silver

Accession For	
NTIS	CRA&I <input checked="" type="checkbox"/>
DTIC	TAB <input type="checkbox"/>
Unannounced <input type="checkbox"/>	
Justification	
By	
Distribution	
Availability Codes	
Dist	Avail. and/or Special
A-1	

FORM 10-1 (Rev. 1-65) 3

NOTICES

DISTRIBUTION: Primary distribution of this report has been made by ARI. Please address correspondence concerning distribution of reports to: U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: PERI-POX, 5001 Eisenhower Ave., Alexandria, Virginia 22333-5600.

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 1994, January	3. REPORT TYPE AND DATES COVERED Final Report Jul 89 to Dec 92	
4. TITLE AND SUBTITLE MANPRINT Support of the Non-Line-Of-Sight Fiber-Optic Guided Missile System			5. FUNDING NUMBERS 63007A 793 1201, 1217 H3, H1	
6. AUTHOR(S) Sanders, William R.				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Research Institute for the Behavioral and Social Sciences ATTN: PERI-IB P.O. Box 6057 Fort Bliss, TX 79906-0057			8. PERFORMING ORGANIZATION REPORT NUMBER ARI Research Report 1660	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) --			10. SPONSORING/MONITORING AGENCY REPORT NUMBER --	
11. SUPPLEMENTARY NOTES --				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE --	
13. ABSTRACT (Maximum 200 words) The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Fort Bliss Field Unit supported MANPRINT evaluations during the Non-Line-Of-Sight (NLOS) Fiber-Optic Guided Missile (FOG-M) System Force Development Test and Experimentation (FDTE), an Extended User Employment (EUE) program, and a Defense Simulation Network-Developmental (SIMNET-D) exercise. Crew performance, human factors, and target cuing impact on system performance were examined. The objectives of this effort were accomplished successfully. The effort developed and executed (1) user-level methods for evaluation, (2) effective strategies for integrating MANPRINT information and requirements into the weapon procurement process, and (3) demonstrations of MANPRINT potential for improving force readiness and system effectiveness. Lessons learned from these evaluations were provided to decision makers to support the acquisition program milestone decisions and the NLOS Critical Design Review process.				
14. SUBJECT TERMS Non-Line-Of-Sight (NLOS) Fiber-Optic Guided Missile (FOG-M) Forward Area Air Defense (FAAD) MANPRINT Air defense			15. NUMBER OF PAGES 119	
			16. PRICE CODE --	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT Unlimited	

Research Report 1660

MANPRINT Support of the Non-Line-of-Sight Fiber-Optic Guided Missile System

William R. Sanders
U.S. Army Research Institute

Field Unit at Fort Bliss, Texas
Michael H. Strub, Chief

Training Systems Research Division
Jack H. Hiller, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

January 1994

Army Project Number
2Q263007A793

Human Factors in Training
Operational Effectiveness

Approved for public release; distribution is unlimited.

FOREWORD

The objectives of this evaluation were to (1) provide or develop user-level methods for human factors evaluation from source selection through fielding of the Non-Line-Of-Sight (NLOS) Fiber-Optic Guided Missile (FOG-M) system; (2) develop effective strategies for integrating Manpower and Personnel Integration (MANPRINT) information and requirements into the NLOS FOG-M system procurement process; and (3) demonstrate MANPRINT potential for improvements to force readiness, system operational availability, fire unit probability of kill, weapon system design, and the optimization of manpower, personnel, and training resources.

The research was performed by the Crew Weapons Performance Team of the Fort Bliss Field Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). This research directly supported the ARI research task, "Soldier-System Effectiveness in Air Defense." The efforts reported here were undertaken at the invitation of the U.S. Army Air Defense Artillery School (USAADASCH), the NLOS Training and Doctrine Command (TRADOC) system manager, and the Operational Test and Evaluation Command (OPTEC).

The concerns and data identified during the course of this project were integrated into the NLOS research and development program through active participation with the NLOS program manager's office, the NLOS TRADOC system manager, the system developer, the System Safety and Health Hazards working groups, and the USAADASCH Directorate of Training Development.



EDGAR M. JOHNSON
Director

MANPRINT SUPPORT OF THE NON-LINE-OF-SIGHT FIBER-OPTIC GUIDED MISSILE SYSTEM

EXECUTIVE SUMMARY

Requirement:

This research is part of an effort to develop and apply concepts, methods, and tools for the evaluation of MANPRINT concerns to support the research and development program of the Non-Line-Of-Sight (NLOS) Fiber-Optic Guided Missile (FOG-M) system. The three broad objectives of this effort were to (1) provide or develop user-level methods for human factors evaluation from source selection through fielding, (2) develop effective strategies for integrating MANPRINT information and requirements into the weapon procurement process, and (3) demonstrate the MANPRINT potential for improvements to force readiness, system operational availability, fire unit probability of kill, weapon system design, and the optimization of manpower, personnel, and training resources.

Procedure:

MANPRINT issue evaluations were conducted for the NLOS pre-production system by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) Fort Bliss Crew Weapons Performance Team. Within the NLOS Force Development Test and Experimentation (FDTE) evaluation, the Performance Team examined soldier task performance and surveyed human factors issues of system design. For Extended User Employment (EUE), the Performance Team carried out a series of low-cost evaluations using the pre-production system and equipment mock-ups. For the NLOS Defense Simulation Network-Developmental (SIMNET-D) evaluation, the Task Force raised the issue of NLOS engagement effectiveness given target cuing time delays inherent in the required command and control system.

Findings:

Results from MANPRINT evaluations can be identified that support each of the three major objectives. The NLOS FDTE MANPRINT effort utilized a human factors evaluation framework directly linked to the MIL STD 1472 Human Factors Engineering (HFE) guidelines that provided a systematic and comprehensive framework for evaluation that was used throughout the follow-on NLOS evaluations. The issue of operator workload was evaluated during field testing using the NASA Task Load Index (TLX) tool. EUE was conducted as a series of separate low-cost follow-up

evaluations of lessons learned from NLOS FDTE and of proposed design changes examining the Gunner's Console design, crew emergency egress, the embedded trainer, crew drill night performance, and the vehicle light signature.

The EUE MANPRINT effort demonstrated the ability of the MANPRINT approach to influence the design of new systems as concerns regarding the overcrowding of the crew compartment and related safety issues lead to the relocation of some equipment items to enhance operator safety. The MANPRINT paper and pencil evaluation of command and control delays and target movement during NLOS engagements demonstrated the ability of the MANPRINT program to isolate and address key issues of system operational effectiveness.

The MANPRINT potential contribution to improved force readiness through error assessment and error reduction can be estimated in terms of dollars through some very simple calculations. For example, from the NLOS FDTE evaluation, a 6% error rate for Launch Control tasks was identified, while program plans called for the acquisition of 16,050 missiles at a cost of roughly \$50,000 each. If Launch Control errors leading to mission failure could be reduced by 50% through training or redesign, the waste of 481 missiles might be avoided, with a cost savings of \$24,075,000.

Utilization of Findings:

The results of the NLOS FDTE MANPRINT evaluations were incorporated into the final test report produced by the TEXCOM Air Defense Artillery Board, Fort Bliss. The results of the EUE MANPRINT evaluations were distributed as formal memoranda through the NLOS Training and Doctrine Command (TRADOC) system manager to the NLOS program manager, the NLOS Human Engineering working group, the NLOS System Safety working group, equipment developers, and other agencies involved in NLOS development. The simple NLOS target movement and search area estimates were of sufficient power to raise the target search issue to the level of a formal test issue for the NLOS SIMNET-D evaluation. The concern that target cuing delays inherent in the required target cuing command and control systems could greatly reduce NLOS engagement effectiveness was supported by the SIMNET-D test data for target detection.

MANPRINT SUPPORT OF THE NON-LINE-OF-SIGHT FIBER-OPTIC GUIDED MISSILE SYSTEM

CONTENTS

	Page
INTRODUCTION	1
Background	1
System Description	1
MANPRINT Goals	3
MANPRINT Approach: Methods for Usability Assessment . .	5
MANPRINT IN FORCE DEVELOPMENT TEST AND EXPERIMENTATION . .	7
FDTE Overview	7
MANPRINT Concerns	7
Method	8
Results and Discussion	11
Conclusions: FDTE Analysis	15
MANPRINT IN EXTENDED USER EMPLOYMENT	18
EUE Overview	18
MANPRINT Concerns	18
Method Overview	18
Evaluation 1: Gunner's Console Design	19
Evaluation 2: Emergency Egress	23
Evaluation 3: Embedded Trainer Characteristics	24
Evaluation 4: NLOS Task Illumination	25
Evaluation 5: NLOS Vehicle Light Signature	26
Conclusions: NLOS EUE Evaluation	27
ESTIMATING NLOS TARGET SEARCH DEMANDS	33
Command and Control Cuing Delays and Target Acquisition	33
SIMNET-D Target Movement and Target Acquisition Evaluation	37
Conclusions: Target Cuing Delays and NLOS Target Acquisition	39
CONCLUSIONS	41
REFERENCES	45

CONTENTS (Continued)

	Page
APPENDIX A. NLOS EUE GUNNER CONSOLE DESIGN EVALUATION . . .	A-1
B. NLOS EUE CREWMEMBER EGRESS EVALUATION	B-1
C. NLOS EMBEDDED TRAINER EVALUATION	C-1
D. NLOS EUE TASK ILLUMINATION EVALUATION	D-1

LIST OF TABLES

Table 1. Crew Drill Error Analysis	12
2. Human Factors Design Review	13
3. Task Load Index (TLX) Subjective Workload Estimates	16
4. Embedded Trainer Target Engagement Task Performance	28
5. NLOS Embedded Trainer Characteristics Evaluation	30
6. Night Missile Reload Times by Crew and Light Source	31
7. Light Source Visibility by Night Vision Goggles (NVG) and Unaided Eye	32

LIST OF FIGURES

Figure 1. Non-Line-of-Sight (NLOS) Fiber-Optic Guided Missile (FOG-M) system	2
2. Fiber-Optic Guided Missile (FOG-M) configuration	4
3. Task Load Index (TLX) rating scales	10
4. Initial system gunner's console design	20
5. Objective system gunner's console design	21
6. ARI objective system gunner's console mock-up	22
7. Gunner performance feedback: Comparison to "window" standard	29

CONTENTS (Continued)

	Page
Figure 8. Engagement event timelines for six command and control methods	35
9. Target travel capability at three speeds during a 10km engagement under six NLOS command and control systems	36
10. Target movement and percentage of movement area searchable by NLOS for a 10km Manual SHORAD Control System (MSCS) engagement	38
11. SIMNET-D command and control cue delays and target availability	40

MANPRINT SUPPORT OF THE NON-LINE-OF-SIGHT FIBER-OPTIC GUIDED MISSILE SYSTEM

Introduction

Background

The Non-Line-Of-Sight (NLOS) Fiber-Optic Guided Missile (FOG-M) system was developed to counter the increasing threat posed by precision guided weapons delivered by rotary wing aircraft masked behind terrain features. NLOS FOG-M uses fiber-optic cable guided missiles to engage stationary and moving rotary wing and ground targets masked by terrain or hidden from direct line-of-sight. The NLOS system requirements are contained in the Capstone Required Operational Capability (ROC) for the Forward Area Air Defense System (FAADS), annex I-NLOS Component, 29 October 1987. Several prototype NLOS systems were constructed to explore aspects of the design prior to soliciting design proposals from industry. Rotary wing and ground targets were successfully engaged with missiles launched from the prototype systems in live-fire demonstrations, and the prototypes participated in numerous technical, operational, and simulation system tests between 1988 and 1991.

In December 1988 the Army awarded a development contract for the NLOS system following a technical competition in which competitors submitted design and cost proposals. On January 23, 1991, the Army terminated the initial NLOS development effort due to projected program cost growth concerns and changing requirements for system capabilities. The program was restarted in March of 1991 for an NLOS that could serve as a ground and air target Combined Arms weapon system with the U.S. Army Infantry School as the lead proponent for the research and development effort. The revised schedule (September 1992) called for the first Army units to be equipped with NLOS in 1999. In a related effort, France and Germany awarded project definition contracts in January 1992 for a fiber-optic guided missile to be used against high-value ground targets.

System Description

The NLOS system consists of a launcher with six missiles, gunner's station, and land navigation system mounted on the high mobility multipurpose wheeled vehicle (HMMWV) (see Figure 1). NLOS is operated by a two-man crew from the 16P Military Occupational Speciality (MOS) currently assigned to the Chapparral air defense system. One crewmember acts as driver and performs radio communications tasks. The second crewmember is the gunner. The NLOS gunner uses the gunner's station controls and displays located in the HMMWV crew cab to enter a missile flight path into the system computer prior to missile launch. The path automatically guides the missile to a designated target area. After launch, the missile seeker provides a look-down view of the battlefield on the gunner's console display via the fiber-optic

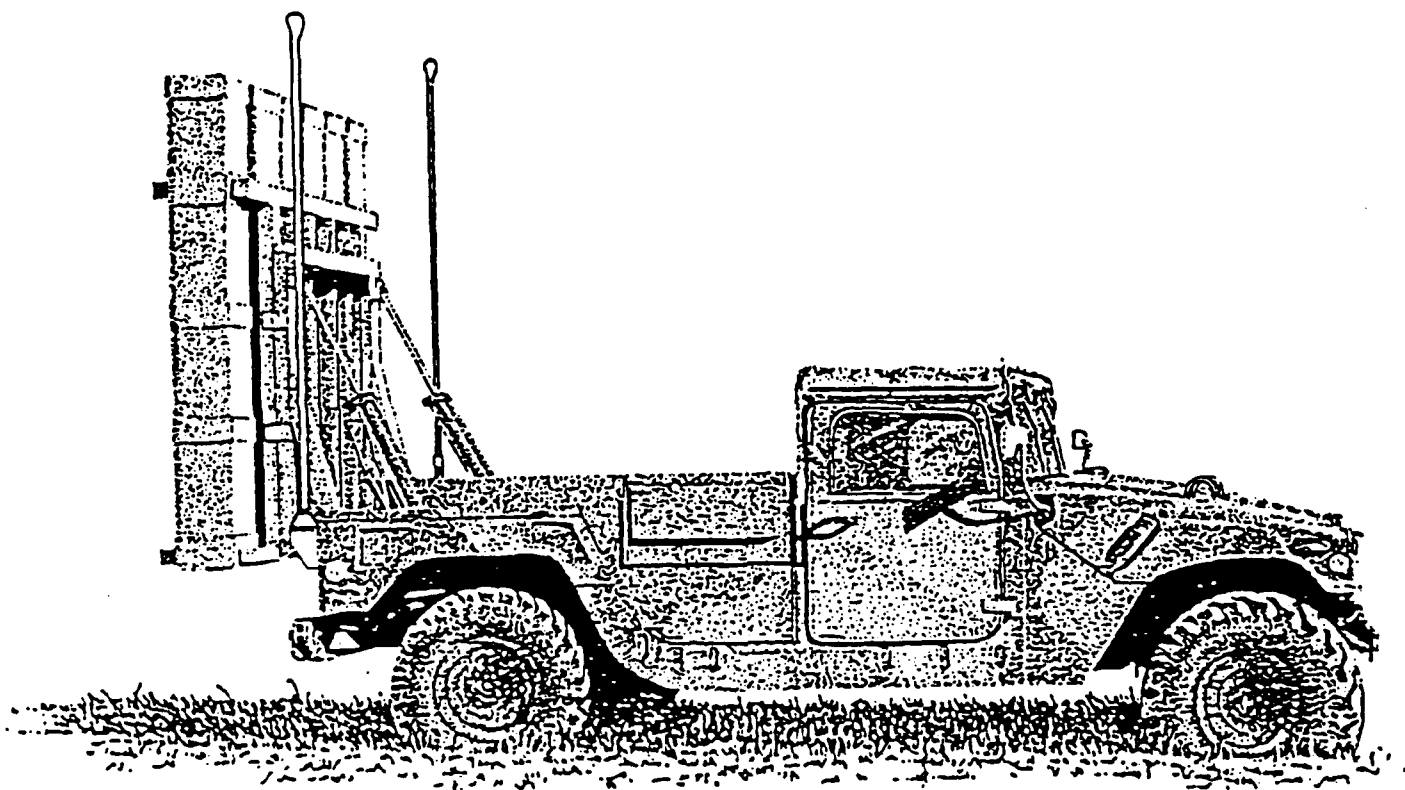


Figure 1. Non-Line-Of-Sight (NLOS) Fiber-Optic Guided Missile (FOG-M) system.

data link while simultaneously transmitting missile guidance commands from the gunner station. The missile seeker is programmed to systematically search the target area until the gunner selects a target for engagement. The gunner has the option to activate an automatic tracker or manually fly the missile into the target using a joystick for guidance control. The NLOS missile is approximately six feet in length with a weight of approximately 150 pounds. A drawing of the FOG-M missile appears as Figure 2.

MANPRINT Goals

NLOS Manpower and Personnel Integration (MANPRINT) evaluations were conducted as part of the NLOS system acquisition effort. MANPRINT refers to the comprehensive management and technical effort to ensure total system effectiveness by the early and continuous integration into materiel development and acquisition of all relevant information concerning the following domains: (1) manpower, (2) personnel, (3) training, (4) human engineering, (5) system safety, and (6) health hazards. The MANPRINT program is described in Army Regulation 602-2 (Manpower and Personnel Integration [MANPRINT] in the Materiel Acquisition Process). The Army Research Institute (ARI) Fort Bliss Field Unit assisted in the implementation of the MANPRINT program by developing and applying concepts, methods, and tools to analyze MANPRINT issues. Specifically, the ARI Crew Weapons Performance Team at Fort Bliss focused on three basic aspects of MANPRINT research and development:

(1) Provide and implement user-level methods for human performance and human factors evaluation, from source selection through fielding,

(2) Develop effective strategies for integrating MANPRINT information and requirements into the weapon procurement process,

(3) Demonstrate MANPRINT potential for improvements to force readiness, system operational availability, fire unit probability of kill, weapon system design, and manpower, personnel, and training.

From 1989 through 1991 the ARI Fort Bliss Field Unit supported MANPRINT evaluations during the NLOS Force Development Test and Experimentation (FDTE), the Extended User Employment (EUE) program, and a Defense Simulation Network-Developmental (SIMNET-D) MANPRINT effort. Efforts were directed at developing concepts, tools, and methods for "soldier in-the-loop" evaluations. Lessons learned from these evaluations provided decision makers with information on key concerns to support the source selection evaluation process, the acquisition program milestone decisions, and the NLOS Critical Design Review decision process. MANPRINT findings were conveyed through test reports, briefings, memoranda and working groups.

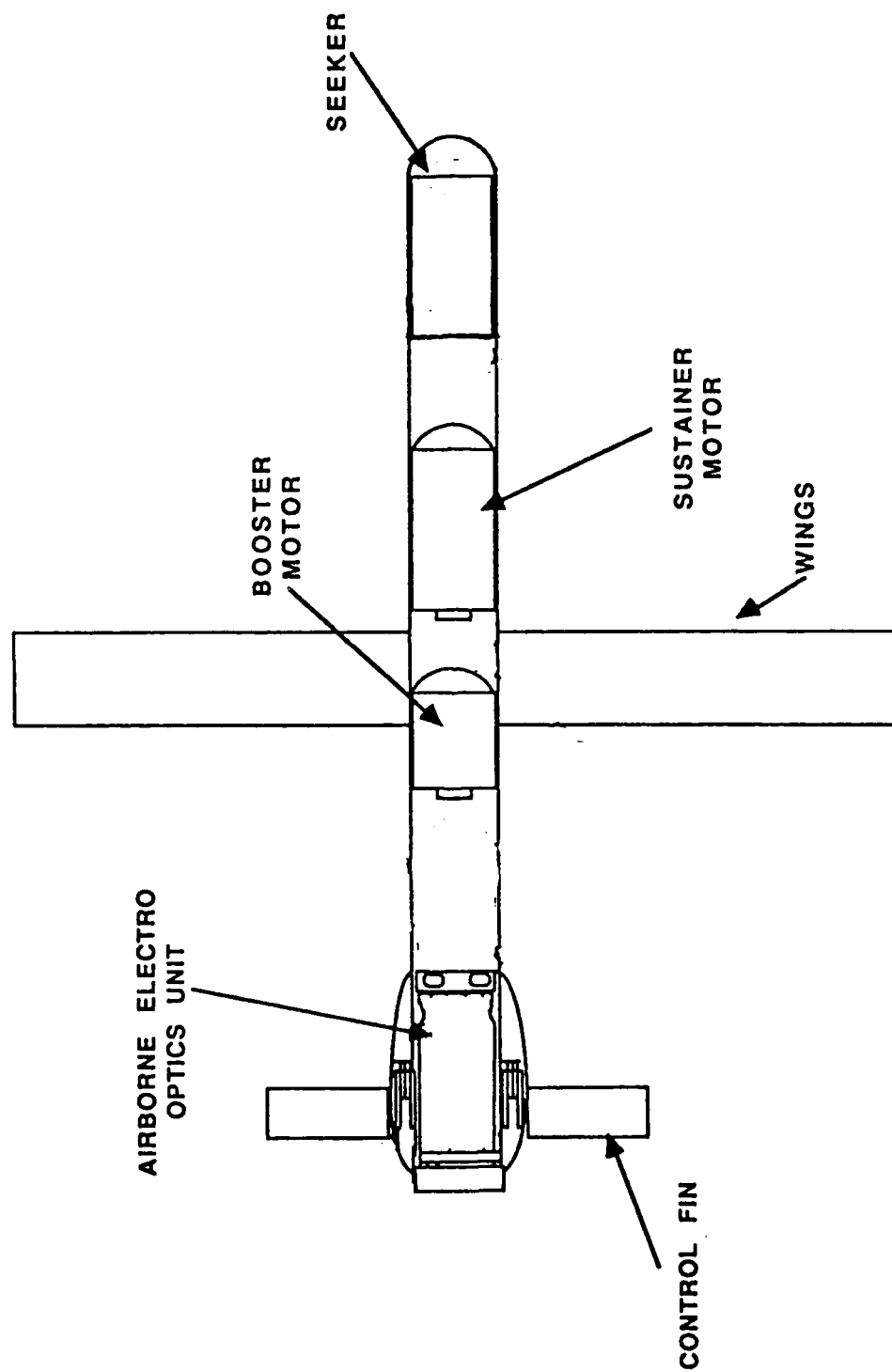


Figure 2. Fiber-Optic Guided Missile (FOG-M) configuration.

MANPRINT Approach: Methods for Usability Assessment

The NLOS MANPRINT support effort was designed to meet the information needs of the research and development effort while working within the constraints of the limited resources available. Whenever possible, the NLOS MANPRINT evaluations were of short duration and conducted during normal duty hours using available equipment and soldiers. The goal of designing usable systems is not unique to MANPRINT. A number of authors have identified methods for developing usable systems that share elements of the MANPRINT philosophy and can suggest useful approaches for MANPRINT evaluations. Key issues in the literature include the relative contributions of quantitative versus qualitative data, the need for examining user behavior in the task environment, the use of mock-ups in design evaluations, the role of theories of cognition in system design, and the adequacy of small sample sizes for gathering user feedback. The NLOS system presents the operator with a sophisticated human-computer interface (HCI); it was reasonable to consider design evaluation guidelines and recommendations from the field of HCI research in deciding on an approach to NLOS MANPRINT evaluation support.

The NLOS MANPRINT effort sought to support the information needs for an evolving system design with evaluations that frequently yielded qualitative data. Booth and Marshall (1989) separate design evaluation efforts into formative and summative evaluations, where formative evaluation is aimed at helping the designer to refine and form the design and primarily uses qualitative data. Summative evaluations typically involve quantitative information based on overall scores on particular measures. The authors contend that these scores, regardless of how they are derived, are unlikely to tell designers what should be done to improve the design. Booth and Marshall (1989) argue that designers will need to know more about why errors or misunderstandings occurred rather than just their absolute numbers. In the later stages of design, quantitative data plays a greater role as designers assess the usefulness of particular changes to a mature system design.

A primary information goal for the NLOS MANPRINT support effort was to understand operator tasks as they exist in an operational military environment. From the HCI usability literature, Whiteside, Bennett, and Holtzblatt (1988) identify the limitations of studying benchmark tasks in a laboratory setting and argue for a "Contextual Research" approach to usability engineering that includes design context factors such as the work environment, time demands, motivational factors, and the need to focus on uncovering the user's personal experience of the system interface. For NLOS "Contextual Research" means exploring the system during the day, at night, and with soldiers wearing chemical and protective suits, and also examining how the soldier and equipment function when things go wrong. The MANPRINT evaluations follow the Whiteside et al. (1988) recommendations to

have soldiers "think aloud" during task performance and relies on videotape recordings as a low cost and flexible data collection technique to understand the nature of the users' work experience.

The NLOS MANPRINT evaluation made extensive use of mock-ups of proposed equipment designs to help users recognize design issues and identify improvements. From the field of HCI usability engineering, Carroll and Rosson (1985) argue that the most important aspect of empirical approaches such as iterative trials with mock-ups is that it encourages the discovery of design solutions that might have been missed in a purely analytic approach. In particular, Landauer (1991) argues that theories of cognition will always be too weak to play an important role in areas such as HCI design. They will not be able to identify system design characteristics more effectively than empirical methods of task and performance analysis and simulation coupled with formative design evaluations. This is in line with the Whiteside et al. (1988) call for "Contextual Research." Landauer (1991) believes that design considerations are extremely sensitive to work context and characteristics of the users, and that task performance simply involves too many variables and is too complex to lend itself to calculations. Landauer (1991) argues for the use of simulations accomplished by simple calculations of task data as a good source of information needed for design work. The NLOS MANPRINT effort used this approach to estimate the time needed for target engagements, and to compare this to the resulting opportunity a target has to move.

A final question to consider in presenting the NLOS MANPRINT support approach is that the evaluations were typically conducted with only four to six trained NLOS crewmembers performing a limited number of task trials. For the purposes of gathering soldier feedback during the development of the NLOS system design, this small sample of trained personnel should be adequate. Exploring the question of how many subjects are enough for usability evaluations, Virzi (1992) found that (1) 80% of usability problems are detected with four or five subjects, (2) additional subjects are less likely to reveal new information, and (3) the most severe usability problems are likely to be detected with the first few subjects. Likewise, Landauer (1991) argues that "tests with 2 to 10 users usually reveal most glaring flaws, and sometimes offer strong guidance for positive improvements."

In summary, the NLOS MANPRINT support approach used small groups of soldiers and equipment mock-ups. This method made it possible to quickly generate soldier feedback on system design issues to satisfy the formative information needs of the equipment developers.

MANPRINT In Force Development Test and Experimentation

FDTE Overview

The NLOS FDTE was conducted 18 April through 22 May 1989 at the North Oscura Range area of White Sands Missile Range, New Mexico. The FDTE employed a single preproduction prototype NLOS system for the test. The primary objectives of the FDTE were to observe operator performance in a tactical environment, refine NLOS crew drills, provide inputs for optimizing system effectiveness, address concepts pertaining to the interface with the manual command and control center, and assist in establishing a baseline for the NLOS production systems. Since the NLOS system simulators/trainers were not available for FDTE, and no live missile firings were scheduled, none of the engagement or training device criteria could be addressed during FDTE. Two key test issues were identified for NLOS FDTE which provided an opportunity to address MANPRINT concerns:

Test Issue 1: Do the individual and collective tasks, crew drills, and TTPs prepare the NLOS squad to optimize the system's performance?

Test Issue 2: Can representative soldiers use equipment provided at the squad level to support the NLOS air defense missions?

MANPRINT Integration. ARI's contribution to FDTE began long before the start of testing through participation in the Required Operational Characteristics (ROC) document development, the MANPRINT Joint Working Group, NLOS acquisition program working groups, and the NLOS Test Integration Working Group. Working within the established system, the team was able to integrate MANPRINT SMMP issues and methods into the NLOS FDTE test plan. Team members served as the Army's Contracting Officer's Representative in managing the efforts of the civilian contractor team gathering and analyzing FDTE MANPRINT data. ARI team members identified the MANPRINT test issues, data requirements, and data collection and reduction methodology for use at the White Sands Missile Range during testing, and in the centralized Data Analysis Group (DAG) at Fort Bliss.

MANPRINT Concerns

The intent of Test Issue 1 was to evaluate NLOS system performance for eleven specific crew drills. The MANPRINT evaluation focused on operator crew drill task performance to include a time and error performance evaluation, error "cause" assessment, and an examination of the adequacy of the proposed two-man team.

The intent of Test Issue 2 was to isolate, document, and correct any personnel or equipment deficiencies that affected mission performance. The MANPRINT evaluation focused on the extent to which the NLOS system conformed to the principles of good human factors design for military systems. The evaluation included the identification of potential system safety and health hazards. MANPRINT calls for the early and continuous evaluation of soldier-oriented design issues throughout the acquisition and development of new systems. The MANPRINT team investigation of system design features and their impact on performance was driven by the desire to demonstrate the value of examining design concerns as early as possible in the acquisition process, where system design flexibility is greatest.

Method

Method Overview. MANPRINT FDTE data collection and evaluation involved integrating information from a number of sources. "MANPRINT cameras" captured soldier task performance video data, while field data collectors recorded significant events for each crew drill. An on-site debriefing of the NLOS crews after each day's missions was used to further explore and identify important aspects of task performance, to include the causes associated with any performance errors. At Ft. Bliss, a MANPRINT team examined and scored crew drill task performance based on multiple sources of crew compartment video, an automated data bus instrumentation system that captured control activation times, and field debriefing information, to support the FDTE "Test-Fix-Test" crew drill development process. A subjective workload assessment was also conducted after crews performed test trials. At the conclusion of field testing, a human factors review was conducted with crewmembers using a structured interview guide.

MANPRINT camera task performance video data. The video information presented on the NLOS Gunner's Console was linked directly by hardware to a recorder, while two "over-the-shoulder" cameras captured the operators' interactions with controls and displays (both audio and video). Video monitors located nearby allowed test personnel to follow soldier performance and record necessary data without intruding on the conduct of the crew drill.

On-site crew drill scoring. Field analysts were present during the course of each crew drill to assess the effectiveness of a drill and to note any factors which might have influenced performance. Performance information was recorded on a "Crew Drill Sheet" tailored to the unique tasks of each crew drill.

On-site crew debrief. Field analysts conducted an on-site debrief of crews after each day's field trials, reviewing selected portions of the day's videotapes to explore concerns with crew drill performance and any observed task performance

errors. The debrief provided a great source of information used in determining the causes of crew drill errors.

DAG error cause coding. The videotape, automated instrumentation, and field notes for each crew drill were forwarded to a central DAG for evaluation, review by the "scoring group", and entry as validated data into the test data base. Where task performance errors were identified, the MANPRINT DAG team reached consensus on the nature of an error and assigned a "MANPRINT Error" code to indicate the most likely MANPRINT domain affected, e.g., System Safety, Human Factors, Manpower. To systematically describe the nature of the problem, one of the following error description codes was assigned to each error: "Procedure Omitted", "Procedure Inaccurate", "Wrong Time" (task performed out of order), "Wrong Procedure", or "Extra Procedure Performed".

Human factors evaluation. The prototype NLOS system was examined to assess how well it conformed to the principles of good human factors design. A structured crew and Subject Matter Expert (SME) debriefing was used. Initial guidance for the evaluation was provided by the Human Engineering Laboratory (HEL) Field Office at Fort Bliss. Guidelines for the evaluation were obtained from two documents: TECOM Human Factors Engineering Guidelines and Human Factors Engineering Data Guide for Evaluation (HEDGE) (Test Operations Procedure 1-2-610, parts 1 and 2, 1983) and TECOM Soldier-Computer Interface Guidelines (Test Operations Procedure 1-1-059, 1985). These guidelines were used to produce a twenty-page structured interview document for gathering data that would meet the information demands of the Human Engineering Design Criteria for Military Systems, Equipment and Facilities, MIL-STD-1472, 1989. The five major areas identified for the NLOS analysis were: operator workspace, displays, controls, soldier-computer interface, and the missile reload equipment. Soldier and SME responses were recorded on the interview guide and included in the NLOS FDTE test report in full, as well as being summarized in a table.

Workload Assessment. Crew workload was a key concern in the NLOS FDTE, particularly where crew drills required substantial physical exertion while wearing the Mission Oriented Protective Posture level 4 (MOPP 4) chemical protective suits. The Task Load Index (TLX) subjective workload rating scale (NASA-Ames Research Center, 1986) was used to gather soldier ratings of the workload involved for the eleven separate drills which make up the total NLOS mission (see Figure 3). The TLX rating scale was administered to crewmembers at the test site immediately following a mission which lasted approximately four hours and consisted of several drills (i.e., System Power Up, Emplacement, March Order). The ratings data were not subjected to a paired-comparison sort procedure because the work of Byers, Bittner, and Hill (1989) strongly suggests that this procedure is unnecessary. Instead, the average of the crewmembers raw ratings on each of the six TLX factors was used.

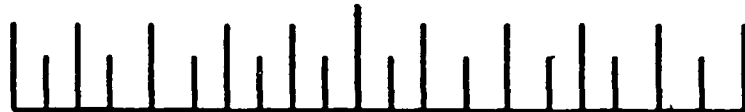
- 1 = DAY MOPP 0
- 2 = DAY MOPP 4
- 3 = NIGHT MOPP 0
- 4 = NIGHT MOPP 4

TLX Rating Scales

Task or Mission Segment: _____

Please rate the task or mission segment by putting mark on each of the six scales at the point which matches your experience.

**Mental
Demand**

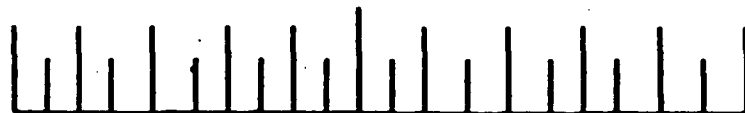


Very Low

Very High

(HOW MENTALLY DEMANDING WAS THE TASK?)

**Physical
Demand**

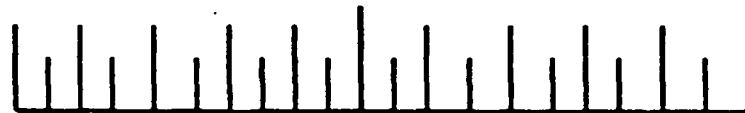


Very Low

Very High

(HOW PHYSICALLY DEMANDING WAS THE TASK?)

**Temporal
Demand**

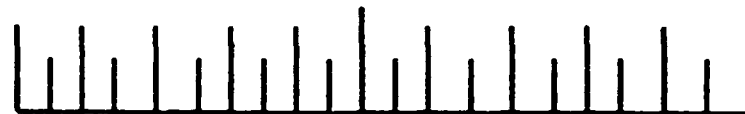


Very Low

Very High

(HOW HURRIED OR RUSHED WAS THE PACE OF THE TASK?)

Performance

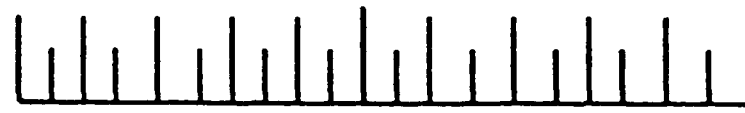


Perfect

Failure

(HOW SUCCESSFUL WERE YOU IN ACCOMPLISHING WHAT YOU WERE ASKED TO DO?)

Effort



Very Low

Very High

(HOW HARD DID YOU HAVE TO WORK TO ACCOMPLISH YOUR LEVEL OF PERFORMANCE?)

Frustration



Very Low

Very High

(HOW INSECURE, DISCOURAGED, IRRITATED, AND ANNOYED WERE YOU?)

Figure 3. Task Load Index (TLX) rating scales.

Results and Discussion

Test Issue 1. Issue 1 addressed crew drill task performance assessment: performance evaluation, error assessment, and the adequacy of the two-man squad. NLOS system performance was evaluated for eleven specific crew drills. Results of the MANPRINT evaluations were incorporated into the NLOS FDTE Test Report (Matthews, Keaton, Jolly, Lewis, Sanders, and Griffith, 1989).

The MANPRINT crew drill error analysis is summarized in Table 1, with a total of 478 errors being identified overall. Multiplying the number of steps in a drill by the number of times the drill was performed yields the total opportunities for error in that drill. As example, System Power Up has 30 steps and was performed 37 times for a total of 1110 opportunities for error. Performance of the eleven crew drills yielded a total of 5,009 drill steps in which an error could occur. The total of 478 errors represents an overall error rate of about 9 percent. The proposed two-man team was thus capable of accomplishing approximately 91 percent of the crew drill tasks to the prescribed standards. Examining the errors which occurred, approximately 40 percent were attributed to procedures being omitted, while procedures performed inaccurately or at the wrong time accounted for 22 and 27 percent of all errors, respectively. Where performance errors occurred they were also classified in terms of which of the six MANPRINT domains (e.g., system safety, health hazards) might be the most likely cause.

There were 610 performance errors. Analysis revealed 133 errors to be associated with the conduct of the task and 477 errors with MANPRINT domains. Ninety-seven percent (465) of these latter errors were attributed to the training domain. The near total attribution of errors to training comes in part from the "Test-Fix-Test" approach to the FDTE evaluation, where tasks and task sequencing were subject to frequent changes during the course of testing which limited the the opportunities for retraining crews. A problem with this error cause coding approach is that it cannot be determined whether training does in fact underlie the observed errors. There is no way of knowing if the errors might persist after tasks and training have been stabilized. If errors did persist, this would suggest that some other aspect of the system is the source of performance errors.

Test Issue 2. Issue 2 examined NLOS system conformity to the principles of good human factors design for military systems, particularly with respect to the issue of man-machine interface under the conditions imposed in an operational environment. This was accomplished through a hands-on review of the system and structured crew and SME debriefs. The five major areas identified for analysis were: operator workspace, displays, controls, soldier-computer interface, and the missile reload equipment. An overview of the Human Factors MANPRINT domain concerns identified is presented in Table 2. One advantage of establishing a MIL-STD-1472-based evaluation framework was that

Table 1
Crew Drill Error Analysis

Crew Drill	Procedure Omitted	Procedure Inaccurate	Wrong Time	Wrong Procedure	Extra Procedure	Total Errors	Drills/Steps	Error Rate (Percent)
System Power Up	12	17	16	3	18	66	37/30	6
System Power Down	22	2	14	0	0	38	36/12	9
Navigation (GC)	55	17	14	2	4	92	27/22	15
Nav (Stand Alone)	23	11	10	0	0	44	18/16	14
Emplacement	8	10	3	1	0	22	18/12	10
Missile Route Plan	1	2	2	1	2	8	18/10	4
Launch Control	25	6	13	1	2	47	50/16	6
Hangfire Misfire	23	9	13	2	0	47	23/17	12
Single Msl Reload	4	11	22	0	6	43	10/33	13
Multimissile Reload	3	15	10	0	11	39	8/36	14
March Order	16	6	9	0	1	32	19/18	9
Totals	192/40%	108/22%	126/27%	10/2%	44/9%	478	5,009	9%

Table 2
Human Factors Design Review

Human Factors Element	Crew and SME Interviews
<p>1. Operator Workspace</p> <ul style="list-style-type: none"> o Workspace Configuration o Seating o Crew Communications o Work Environment 	<ul style="list-style-type: none"> o Driver space adequate; gunner space cramped; needs rifle and tool storage, writing surfaces o No gunner's seat adjustment o Limitations when off-vehicle, in MOPP4 o Crew cab heat, toxic fumes when under camouflage, needs crew cab and reload illumination
<p>2. Controls</p> <ul style="list-style-type: none"> o Dimensions o Resistance o Location 	<ul style="list-style-type: none"> o Good control grip speed and accuracy o Good Programmable Display Pushbutton (PDP) tactile response o Good view and reach of pushbuttons and switches
<p>3. Displays</p> <ul style="list-style-type: none"> o Size, Viewing Distance, and Angle o Document Holders o Display Format and Content 	<ul style="list-style-type: none"> o Size adequate, screen glare a problem, forward lean observed o Target data display (used windows, map, paper) o Call for fire message vs. target data display
<p>4. Soldier-Computer Interface</p> <ul style="list-style-type: none"> o Data Entry Procedures o Interactive Control o Feedback o Error Management/Data Protection 	<ul style="list-style-type: none"> o Entries validated, indicates acceptance, delays o Good menus, data entries echoed on screen o Good prompts, error messages, default values o Adequate error correction in menus, error messages

Table 2
Human Factors Design Review (cont.)

Human Factors Element	Crew and SME Interviews
<p>5. Missile Reload Equipment</p> <ul style="list-style-type: none"> o Reach, Lift, Push, Pull Tasks o Step Points and Handholds o Fasteners and Connectors o Operating Environment 	<ul style="list-style-type: none"> o No lifting, moving problems cited, some reach limitations o Improve step and handholds, canister handholds o Canister hoist lug, rail and pin tolerances, location of 5331 connector, six-pack hoist lugs o Night reload needs illumination

this perspective results in identifying what is good about the system design as well as any potential deficiencies, so that the Human Factors review goes beyond a simple list of complaints. Giving the design a full review to identify both strengths and weaknesses makes this evaluation more acceptable to the equipment developers as a starting point for the discussion of concerns.

Many of the Human Factors MANPRINT concerns identified early in FDTE would remain issues throughout the NLOS development program. Lack of gunner work space was identified as a concern and set the stage for later issues when equipment additions and a Gunner's Console redesign were proposed. Crew cab heat remained a design issue of major proportion throughout development. On-site MANPRINT data collectors noted that the NLOS crews would use scraps of paper, and even the vehicle windows, as a surface on which to record critical target data messages, suggesting yet another design inadequacy. This observation was recorded as a "Data Display" concern. The review of the missile reload equipment led to the identification of simple or common sense design issues, such as the need for steps and handholds for on-vehicle tasks. The MANPRINT team pointed out that the conduct of FDTE night operations was flawed by providing crews with supplementary lighting sources to meet task illumination requirements. System Safety and Health Hazard MANPRINT domain concerns identified during the evaluation include excessive heat and vehicle exhaust fumes in the crew compartment, and concerns about equipment design and procedures used in single missile reload.

Results of the TLX workload evaluation were consistent with the crew debrief results. From the crew debrief, crewmembers stated that the workload required during single missile reloads and particularly the unloading of full weight missile canisters using the prototype missile reload equipment was excessive. The average of the six TLX subjective workload ratings for the single missile reload battle drill (32.47) was significantly higher than the average of the remaining nine non-reload drills (11.74) [$F(1,30) = 45.8, p < .0001$]. Likewise the average rating for multiple missile reload (23.38) was significantly greater than the average for the remaining nine non-reload drills (11.74) [$F(1,30) = 8.0, p < .001$]. While the relative level of workload for the two reload drills was greater than that for the other drills, the means for all the drills were well below the scale value of 50 which marks the center point on the rating scale (see Table 3).

Conclusions: FDTE Analysis

The FDTE analysis was a valuable means of capturing soldier-oriented information early on in system development. Performance scoring attempted to go beyond the tallying of errors to include the identification of the nature and source of errors encountered through the use of error "cause codes" on scoring sheets, but this approach met with only limited success. The score sheets were a good means of recording the behaviors

Table 3
Task Load Index (TLX) Subjective Workload Estimates

	Mental	Physical	Temporal	Performance	Effort	Frustration	Average
Crew Drill	1/ 23	1/ 16	1/ 16	2/ 12	1/ 18	1/ 22	17.8
System Power Up	6	8	9	4	8	15	6.3
System Power Down	20	9	12	12	15	22	15.0
Navigation (GC)	12	8	7	8	16	18	9.8
Nav (Stand Alone)	13	16	12	8	16	22	14.8
Missile Route Plan	20	7	8	4	10	18	11.2
Launch Control	20	8	12	8	14	21	13.8
Hangfire Misfire	7	4	4	2	3	15	5.8
Single Msl Reload	19	37	24	14	46	56	32.7
Multimissile Reload	20	30	22	10	29	30	23.5
March Order	12	10	5	5	9	15	9.3

1/ How demanding was the task? 0 = Very Low Demands, 100 = Very High

2/ How successful were you in accomplishing what you were asked to do? 0 = Perfect Performance, 100 = Failure

associated with errors, but the cause of the error was almost always identified as training, which could not be confirmed. Scoring of performance errors attributed 76 percent of all errors to training causes, and 22 percent to test conduct related problems not associated with a particular MANPRINT domain. While the errors could be the result of the frequent changes introduced to the drills and crewmembers simply forgetting what the currently "correct" procedure was it is not possible to rule out other potential causes, such as system design features or manpower resources. Approximately 40 percent of all task performance errors were due to procedures being omitted. In most cases, these omissions were not critical, such as a crewman's failure to make a redundant vocal announcement to indicate that he had performed a specific task.

While the error cause coding scheme did not generate useful information, the MANPRINT paragraph summarizing performance for each crew drill was extremely valuable in providing the reader with a plain english description of what occurred. The quantitative time and error performance data presented in the FDTE Test Report could often hide very simple explanations of what crewmembers actually did to perform their tasks. For example, in the single missile reload drill, crewmembers consistently committed a high number of task performance errors according to the test criteria. Upon examination it was found that crewmembers were simply performing their tasks in a more logical and efficient order than that prescribed in the drills they were trained on. What was really needed was a change in the drill, not the soldier task performance.

The human factors review identified a number of concerns which were investigated in follow-on NLOS evaluations. The focus on displays, controls, workspace, soldier-computer interface, missile reload equipment concerns, and reliance on MIL-STD-1472 human factors engineering guidelines remained throughout NLOS testing. From the operator workspace review, a lack of workspace within the crew cab and concerns about cab heat were noted. It was noted that the conduct of FDTE night operations was flawed in that crews were allowed to make excessive use of light sticks to meet task illumination requirements. This brings into question the validity of the night operations crew drill performance findings and the adequacy of NLOS design for night operations.

The NLOS Embedded Trainer evaluation originally scheduled for FDTE was not conducted due to the late arrival of the training device. It was originally planned to investigate whether the Embedded Trainer could be used to teach crewmen the skills required to guide an NLOS missile to target and to operate the fire unit. The absence of training devices severely limited the ability to investigate NLOS engagements during FDTE. A key MANPRINT issue that was identified, but which could not be evaluated, was the ability of the NLOS system to detect moving targets given current command and control system target cuing time delays. The issue was noted in the FDTE Test Report for later evaluation.

MANPRINT In Extended User Employment

EUE Overview

During the period from January through September 1990, the ART Fort Bliss Field Unit conducted evaluations in support of the NLOS Extended User Employment (EUE) program. The ART Crew Weapons Performance Team facilitated the integration of MANPRINT into the NLOS EUE program by developing and applying concepts, tools, and methods to analyze several specific MANPRINT issues. The Air Defense Artillery (ADA) School EUE evaluation plan was to use the prototype NLOS fire units to refine air defense doctrine, tactics, techniques, and procedures. EUE would also provide a source of technical and operational data. Other agencies had an opportunity to explore concepts through their own evaluations using the NLOS platoon during EUE.

MANPRINT Concerns

NLOS EUE efforts were directed at developing concepts, tools, and methods for low cost "soldier in-the-loop" evaluations. The evaluations provided decision makers with information on key concerns in a timely manner to support the research and development program decision schedule. Specifically, NLOS EUE support was directed toward a follow-up evaluation of lessons learned from NLOS FDTE and toward an investigation of proposed system design changes. Specific issues identified for evaluation were as follows:

- (1) Gunner's Console Objective System Design,
- (2) NLOS Fire Unit Emergency Egress,
- (3) Prototype System Embedded Trainer Characteristics,
- (4) NLOS Task Illumination,
- (5) Vehicle Light Signature Evaluation.

Method Overview

The scope of each evaluation was restricted to a limited set of design features or a single crew drill so that evaluations could be conducted with available resources, typically during normal duty hours, and as soldier duty schedules permitted. Videotape recordings were used as a primary means of data collection, minimizing the need for test support personnel. Inexpensive equipment mock-ups were used as a tool for gathering early soldier input on proposed design changes. "Motor Pool" and one-day local training area exercises were used as a quick and inexpensive method for gathering information which did require an operational environment. The key requirement of each evaluation

was to approximate tactical realism on only those dimensions relevant to the evaluation (i.e., focus on crew egress tasks, or capture performance data on the embedded trainer).

Evaluation 1: Gunner's Console Design

Concerns. During NLOS FDTE it was observed that the crew compartment space was very limited. A contractor proposed Gunner's Console redesign configuration, presented as an engineering drawing, raised the concern that crew space might be further reduced, thus raising additional safety concerns.

Method. ARI personnel built mock-ups of the proposed equipment design so that an early "soldier-in-the-loop" hands-on evaluation by NLOS gunners might be conducted. A sheet metal and plastic mock-up was fabricated by Fort Bliss engineers for use in the static evaluation of the design. For field testing, a styrofoam and cardboard mock-up of the gunner's console was used, which was assembled in only a few hours. Figure 4 presents an illustration of the prototype system Gunner's Console design used in FDTE. An illustration of the proposed objective system design appears as Figure 5. A photo of the ARI produced objective system Gunner's Console mock-up used in the evaluations appears as Figure 6. On 16 and 19 February, 1990, NLOS gunners participated in a review of the physical design characteristics of the proposed Gunner's Console using mock-ups of the equipment in a HMMWV. The evaluation included a static motor pool review and also mobile field trials at a local training area.

Results. The evaluation generated a large number of detailed comments from the crewmembers regarding features of the proposed design and specific recommendations for changes. The Formal Memorandum: NLOS EUE Gunner Console Design Mock-Up Evaluation, dated 23 February, 1990, contains the crewmember comments and is included as Appendix 1. Briefly, gunners stated that the proposed console design blocked the forward vision of the gunner's position and partially blocked the side vision of the driver. The short distance between the console screen and gunner's face was seen as a safety hazard, though gunners did not wish to have the console located under the dash as in earlier system configurations. These results were presented at an NLOS Controls and Displays Design Review, and at the NLOS Human Engineering Working Group (HEWG) Meetings. The HEWG adopted the identified concerns as issues for future evaluation.

MANPRINT concepts, methods, tools. The MANPRINT concept of focusing on soldier issues as early as possible in new system acquisition is in reaction to the decreasing flexibility of equipment design over time as available design engineering dollars are spent. Users have a responsibility to begin exploring the "soldier-equipment fit" issue as soon as early design concepts are identified to influence the design of equipment to meet their own needs. Equipment mock-ups proved to be valuable tools which go well beyond line drawings in

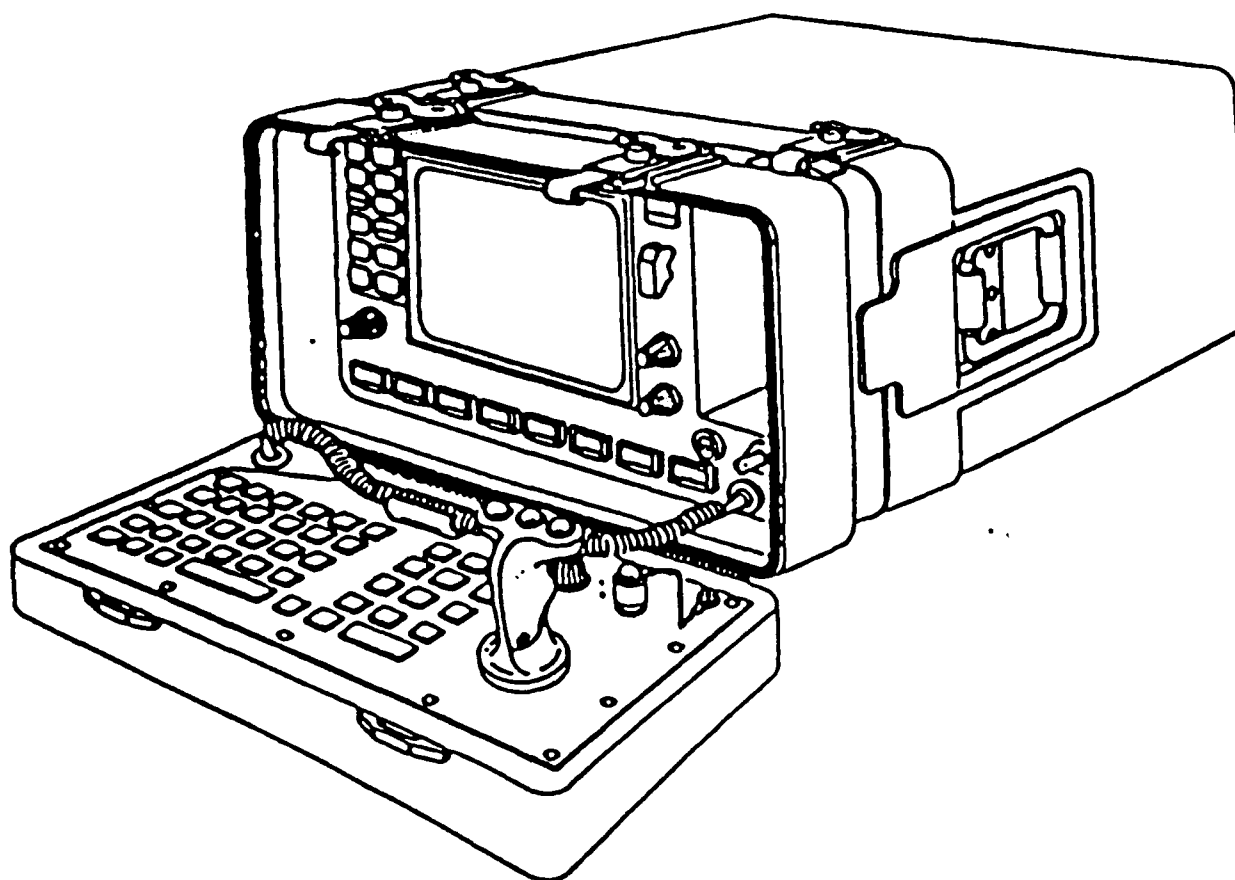


Figure 4. Initial system gunner's console design.

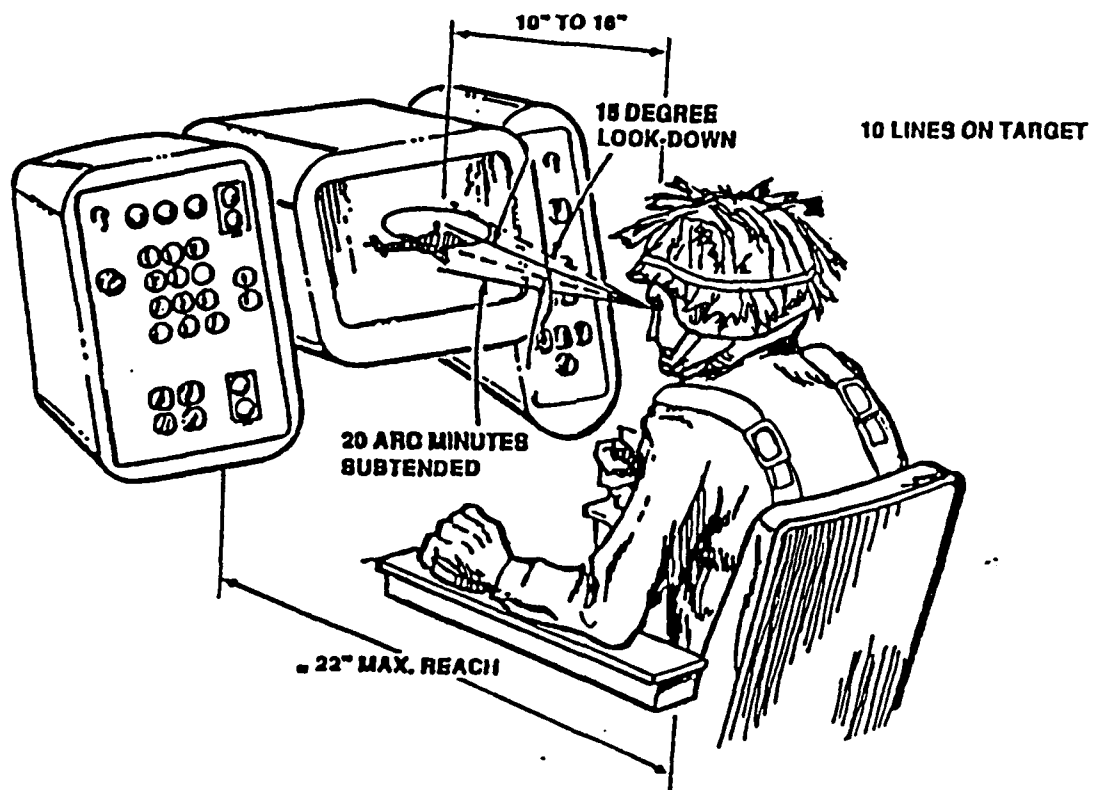


Figure 5. Objective system gunner's console design.



Figure 6. ARI objective system gunner's console mock-up.

eliciting early user input on proposed designs. Many who had taken a "wait and see" position about the new design had immediate insights, and could suggest improvements to enhance the "soldier-machine fit" of the system after having the opportunity to experience the mock-up of the total workspace environment. By the time of Critical Design Review (CDR) the proposed NLOS design was mature, and user input was sought for this specific design, rather than for proposing alternative design elements or approaches to design requirements. Valuable user insights can be gathered through such techniques as the use of mock-ups, but if user input is to have an impact on system design, this must occur very early in the design phase, before engineering dollars are spent and design flexibility is gone.

Evaluation 2: Emergency Egress

Concerns. Changes proposed for the NLOS objective system included the addition or redesign of equipment within the crew cab which would significantly reduce available space. The concern was raised that this equipment might block the escape of a crewmember from the crewcab if the vehicle doors were blocked in an accident. No egress requirement was stated in the NLOS system specifications, perhaps because safe egress is assumed for systems based on the standard HMMWV vehicle. The Crew Weapons Performance Team chose to examine the impact of adding the new equipment to the existing HMMWV operator workspace.

Method. An evaluation was conducted to identify how well soldiers could climb over the equipment separating the two cab seats to exit the vehicle. On 24 May, 1990, sixty-four emergency egress trials were videotaped and timed where both crewmen were required to exit through the same NLOS vehicle door. Major pieces of NLOS equipment (air plenum, radios, gunner's console) were built as mock-ups and placed in the crew cab. Videotape recordings were made of each trial to aid in identifying specific features of the system design that impacted egress performance, and to create a flexible database for post hoc analyses. The evaluation captured the time required for both crewmembers to egress out the driver's door, and the gunner's door, under conditions of MOPPO (no chemical protective equipment) and MOPP4 (full chemical protective oversuit and mask).

Results. The Formal Memorandum: NLOS EUE Crewmember Egress Evaluation, dated 30 August, 1990, details the results of this evaluation, and is included as Appendix 2. The memorandum identifies the design features which aided crewmembers, and those which impeded their progress in exiting the vehicle, and details trials where crewmembers became entangled in equipment and were unable to leave the vehicle. Egress was shown to be a difficult but achievable task. An inexperienced gunner needed as much as 60 seconds to exit the vehicle, while the same gunner, with experience, could exit the vehicle in an average of about 15 seconds. Performance was thus very dependent on experience or training. An analysis of variance test confirmed that there is no significant difference between the egress times for the

conditions of MOPPO (13.73) and MOPPO4 (13.73) [$F(1, 57), = 0.00, p > 0.9997$] for the 59 trials where soldiers successfully egressed from the vehicle. Findings were briefed at the 4 June NLOS HEWG meeting at the Boeing (Huntsville, AL.) facility using the videotaped performance trial recordings to support the summary data. The egress concern was formally adopted as a HEWG design issue. The contractor implemented changes in the objective system design, relocating radio equipment out of the crew cab, thereby directly addressing the egress design concerns.

MANPRINT concepts, methods, tools. The emergency egress evaluation reflected an emerging user level concern and was not a formal NLOS design requirement. Early user input did influence system design, as focusing attention on this safety concern led the contractor to make adjustments in the proposed design, moving electronic equipment from the crew cab to the rear of the vehicle and thus increasing crew cab workspace. In this case the early soldier-in-the-loop MANPRINT concept worked well to shape system design.

Evaluation 3: Embedded Trainer Characteristics

Concerns. The NLOS Embedded Trainer (ET) provided both "Fixed" scenarios which are entirely preprogrammed, and "Variable" scenarios which allow the gunner to select his initial fire unit location. The ET is the prime source of sustainment training for the NLOS system. The trainer was not available for FDTE testing, making it a prime candidate for user evaluation during the follow-on EUE program. The Crew Weapons Performance Team elected to evaluate the NLOS ET system in terms of eleven required technical characteristics for embedded training systems that had been identified by Purifoy, Ditzian, and Finley (1989) to ensure that ET concerns were addressed in a consistent and comprehensive manner. The eleven required characteristics include such areas as Training Content, Levels and Types of Training, Feedback of Performance, and Logistics Burden issues as criteria. A video camera was positioned over the right shoulder of the gunner in the NLOS fire unit to record both audio and video data for crewmember performance on twelve simulated engagements.

Results. Videotapes were reviewed to identify soldier performance tasks associated with the NLOS prototype Embedded Training system and preliminary tasks lists were created. Target engagement task performance times and ranges to target area for twelve trial scenarios were compiled for preliminary evaluation of gunner task performance trends, and as a first step toward identifying measurable performance standards or criteria for each scenario. Task performance time and range data for NLOS Target Engagement Scenario #6 is provided as Table 4. The time and range data for task performance in Table 4 shows some apparently odd trends for the tasks of zooming and slewing the missile seeker, where the gunner manipulates these controls long before a target could be present. From observations and discussions it

was found that gunners would test these system functions by manipulating them early in engagements to ensure that they were working. Examples of performance feedback displays which could be provided to the gunner to enhance training were developed. An example of a possible feedback display for a gunner is provided as Figure 7. A preliminary MicroSAINT soldier performance computer model was developed incorporating NLOS ET tasks and task performance times. The evaluation of the NLOS Prototype Embedded Training system in terms of the eleven characteristics is summarized in Table 5. Memoranda reporting results of the ET evaluation were provided to the NLOS TRADOC System Manager (TSM) for use in developing NLOS engagement task performance scoring criteria. The Formal Memorandum: NLOS Embedded Trainer MANPRINT Evaluation, dated 22 February, 1991, detailed the results of this evaluation, and is included as Appendix 3. This memorandum presents data for three trials on each of four ET scenarios as well as a more in-depth discussion of the gunner tasks, the MicroSAINT model, and detailed comments for each of the eleven required technical characteristics of embedded training systems.

MANPRINT concepts, methods, tools. The MANPRINT evaluation applied the ARI/PM TRADE Embedded Training evaluation scheme to the prototype NLOS Embedded Trainer to generate early soldier performance and training effectiveness information for equipment designers and decision makers. The eleven characteristics scheme offers a useful format for reviewing ET systems early in their development. The need for performance feedback and standards is essential to training effectiveness. Examples of feedback displays were developed from actual NLOS ET soldier performance data.

Evaluation 4: NLOS Task Illumination

Concerns. Light discipline was not enforced during the conduct of NLOS FDTE night crew drills. This lack of realism may have led to an overestimation of NLOS crew performance, i.e., quicker performance times and fewer errors. A related issue which arose during discussions with acquisition program members was that alternative light sources existed which have a lower light signature than the standard Army issue flashlight. During NLOS EUE, a follow-on evaluation of night crew drill performance under conditions of light discipline was conducted. On 25 September 1990, eight single missile reload battle drills were carried out in a simulated night environment in a maintenance building at Fort Bliss. A video camera equipped with a night vision device was used to record gunner task performance. The video recording was reviewed to extract task performance times when a standard issue flashlight with a red filter was used and when a prototype low signature Cluster Map Light (CML) flashlight was used. The infrared signature of the red filter flashlight, a blue-green filter flashlight, and CML flashlight lined up side by side was recorded on video tape to provide a comparison of their relative signature sizes.

Results. The Formal Memorandum: NLOS EUE Task Illumination MANPRINT Evaluation, dated 10 December 1990, detailed the results of this evaluation, and is included as Appendix 4. The crews were able to perform reload tasks and displayed similar task performance times with both the red filter and CML flashlights (see Table 6). The general finding was that crews could perform single missile reload tasks with little or no illumination. In comparison to the standard issue red filter flashlight, the blue-green filter reduced the flashlight signature to about 60%, while the prototype CML flashlight signature was only about 11% of that of the red filter flashlight. Gunners recommended adding light source brackets in the crew cab area on the radio rack to allow for lap level illumination. There was no recommendation for adding light source brackets on exterior points of the vehicle to aid missile reload task performance. These findings were presented at a 30 October 1990, NLOS briefing at Fort Bliss.

MANPRINT concepts, methods, tools. The task illumination evaluation showed that night operations could be conducted in equipment bays to address equipment design issues. This one-day, no cost, motor pool evaluation allowed for more repetitions of the single missile reload night crew drill than had occurred in the previous four weeks of field testing. The night vision video recordings of soldier performance were extremely useful in minimizing the human data collector requirement and in allowing for detailed post-trial time analysis.

Evaluation 5: NLOS Vehicle Light Signature

Concerns. The experience of watching NLOS crews perform crew drills at night raised the concern that the light signature given off by the vehicle electronics and crew flashlights would make the system vulnerable to detection and attack in an operational environment. The Crew Weapons Performance Team raised this concern at an NLOS Human Engineering Working Group meeting and agreed to pursue the question in more detail. The task was to identify a low cost method and criteria for measuring vehicle night illumination signature that could be used early in system development, and to apply this method to the prototype NLOS system so as to establish a preliminary night signature baseline. The Army Human Engineering Lab (HEL) provided the criterion that light sources should not add to vehicle detectability at a distance of 50 meters. Subjective estimates of light source signature size were collected by three independent observers. Two used PNV-4 night vision goggles. One observer did not use any vision aids. Light signature estimates were made from four locations in a 50 meter circle extending from the vehicle to provide a front, right, rear, and left side view. Five light sources were evaluated, the white light coming from the NLOS Gunner's Console, red filter and blue-green filter flashlights, a low signature cluster flashlight, and a low signature cluster map light. Data collection took place on the night of 27 September in a local training area at Fort Bliss.

Results. Results of the light source signature evaluation are summarized in Table 7. Gunners stated that they had adequate illumination for task performance with each of the light sources. Night task performance using the current Army issue red filter flashlight produced a vehicle signature detectable to night vision goggles and the unaided eye at a distance of 50 meters from the vehicle, when observed from the four viewing positions separated by 90 degrees. The blue-green flashlight filter, and the CML flashlight and cab light illumination sources yielded a vehicle signature that was very difficult to detect with night vision goggles or the unaided eye from any point at a 50 meter radius from the vehicle. These findings were presented at the 30 October 1990, NLOS Laydown briefing at Ft Bliss, Texas.

MANPRINT concepts, methods, tools. The vehicle light signature evaluation resulted in a simple procedure and set of performance criteria that can be used in a one-day evaluation of any system. The thrust of the effort was to validate and quantify the MANPRINT concern regarding NLOS night signature, and to provide an example to the NLOS acquisition community of how low cost evaluations could be conducted early on in system development. The results suggest that the low signature light sources might be a useful alternative to the current flashlights.

Conclusions: NLOS EUE Evaluation

The NLOS Extended User Employment MANPRINT efforts were directed at developing and applying concepts, methods, and tools to analyze NLOS system concerns. During NLOS EUE, the opportunity existed to conduct low cost "soldier in-the-loop" evaluations to generate user data and to provide decision makers with information on key concerns. Several lessons learned can be identified from the effort. An EUE program can provide a valuable opportunity for follow-up evaluations based on lessons learned from the broader testing program. Earlier is better when investigating "man in the loop" concerns because design flexibility decreases rapidly after a design concept is identified. Evaluations of limited scope can be conducted quickly and inexpensively in the user motor pool or local training area with commonly available resources. Such evaluations can provide a valuable "quick look" at user concerns to determine whether these need to be raised as formal issues within the system research and development program. Simple mock-ups of proposed equipment can generate valuable insights that can influence system design when identified early. The use of video tape recordings of crew and system performance is a flexible and low cost method which supports both data collection and analysis. Finally, the use of video taped crew performance is a powerful means of conveying safety concerns to system developers.

Table 4
Embedded Trainer Target Engagement Task Performance

Engagement Tasks	Trial 1 *Time/**Range	Trial 2 *Time/**Range	Trial 3 *Time/**Range
Enable Fire	00/5150	00/5150	000/5150
Auto Search Start	08/4500	00/4500	008/4500
Zoom Seeker Manually	36/1480	10/4200	018/3458
Slew Seeker Manually	11/4143	12/3900	022/3086
Target In FOV	07/4560	12/3900	015/3880
Target Detected	11/4143	13/3800	016/3500
End Seeker Slew	30/2229	18/3310	034/1640
First Lock-On Try	30/2121	40/1200	036/1481
First Break-Lock	30/2067	None	048/499
Second Lock-On Try	33/1906	None	109/499
Second Break-Lock	None	None	None
Target Identified	Don't Know***	Don't Know***	Don't Know***
Missile Hits Target	48/Hit	48/Hit	122/Hit

* Cumulative engagement time in seconds from launch/range to original target area in meters.

** Decreasing range to target area stops arbitrarily at 499 meters.

*** No required action associated with Target Identification task.

<u>ENGAGEMENT TASK</u>	<u>WINDOW STANDARD</u>	<u>STUDENT PERFORMANCE</u>
1. CUE TO LAUNCH TIME	20-30 SECONDS	20 SECONDS
2. BREAK AUTO-SEARCH (TARGET IN FOV)	4560-3500m	4143m
3. SEEKER LOCK-ON - RANGE - ZOOM	2000-1000m NARROW FOV	2121m WIDE FOV
4. TARGET IDENTIFICATION	TRUE FRIEND (DON'T LOCK-ON)	FALSE THREAT (LOCK-ON)
5. INTERCEPT	NO	YES
<p>STUDENT GRADE: FAIL (SEE FEEDBACK BELOW)</p> <p>*DO NOT ATTEMPT SEEKER LOCK BEYOND 2000m</p> <p>*DO NOT ATTEMPT SEEKER LOCK IN WIDE FOV</p> <p>*REVIEW AH-64 APACHE HELO IDENTIFICATION</p> <p>TRAINING TASK: REPLAY SCENARIO #6</p>		

Figure 7. Gunner performance feedback: Comparison to "window" standard.

Table 5
NLOS Embedded Trainer Characteristics Evaluation

1. TIME REQUIRED TO TRANSITION INTO AND OUT OF ET. Gunners transition into and out of ET in 10-15 seconds.
2. ET LOGISTICS BURDEN. No ET logistics concerns were identified.
3. LEVELS AND TYPES OF TRAINING DELIVERED BY ET. Concern: Content is limited to target engagement, could be broadened in scope to optimize total POI ET sustainment training potential.
4. NUMBER AND TYPES OF TRAINING DELIVERED BY ET. "Variable" scenarios provide flexibility needed to prevent memorization.
5. TRAINING CONTENT OR TOPICS. Concern: The prototype ET system automatically provides a target intercept point to the gunner. This artificial feature eliminates key mental task training.
6. NEED FOR INSTRUCTORS OR TRAINING MANAGERS WHEN USING ET Gunners exercise ET without assistance, replay with on-board videotape.
7. REQUIRED LEVEL OF FIDELITY OF SIMULATIONS. Constraints: Single missile, daylight only, no target identification, no time pressure to launch, automatic target intercept calculation.
8. PERFORMANCE EVALUATION AND ASSESSMENT CAPABILITY. Concern: No performance summary or record except videotape. No diagnostic comparison of task performance to standards.
9. PERFORMANCE DATA SECURITY. The only potential data source is the optional videotape record.
10. FEEDBACK IN SUPPORT OF EFFECTIVE LEARNING. Concern: No performance feedback against a standard.
11. ET ADAPTABILITY, RESPOND TO SOLDIER PERFORMANCE AND STRENGTHEN WEAK AREAS. Concern: Need to evaluate performance and provide a software message to direct gunner to appropriate ET scenario or lesson in a training matrix.

Table 6
Night Missile Reload Times By Crew and Light Source

Crew \ Source	Red Filter	Cluster Light	Red & Cluster
Crew 1	7 min 40 sec	6 min 12 sec	6 min 56 sec
Crew 2	8 min 22 sec	8 min 46 sec	8 min 34 sec
Crew 1 & 2	8 min 01 sec	7 min 29 sec	7 min 45 sec

Table 7**Light Source Visibility by Night Vision Goggles (NVG) and Unaided Eye**

Viewing Angle Light Source	0 Degrees NVG/Eye	90 Degrees NVG/Eye	180 Degrees NVG/Eye	270 Degrees NVG/Eye
Gunner's Console	Yes/Yes	No/No	No/No	No/No
Red Filter	High/Yes	High/Yes	*High/Yes	High/No
Blue-Green Filter	Minimal/No	Low/Yes	No/No	No/No
Cluster Cab Light	No/No	No/No	No/No	No/No
Cluster Flashlight	No/No	Low/No	No/No	No/No

* Red Filter light source visible through vehicle right mirror reflection.

Estimating NLOS Target Search Demands

Command and Control Cuing Delays and Target Acquisition

Total system perspective: Command and control delays. NLOS typically depends on an independent sensor or forward observer to provide the target information needed for engagements. This introduces delays ranging from a few seconds to several minutes before the information arrives at the NLOS. The time required to send target information to the NLOS, and for the NLOS to send a missile to the target area, provides an opportunity for the target to move from its original location. As engagement time increases the potential area in which a target could move also increases, while the proportion of this target area that can be covered by the missile's field of view decreases. A major question surrounding the fielding of NLOS is whether the system will be able to find targets using current command, control, and intelligence (C2I) systems, or whether NLOS is dependent upon a future C2I system to provide near realtime transmission of target information and a target location update. The NLOS target search capability was a key MANPRINT concern. As longer target cuing delay times allow for greater target movement, successful target acquisition should depend increasingly on the skills and abilities of the gunner to rapidly integrate information and predict a target intercept location.

To address the question of NLOS target search effectiveness given C2I constraints, the Crew Weapons Performance Team developed a series of simple distance and area calculations to estimate the proportion of the potential target movement area that NLOS can search as a function of target cuing delays. Engagement times corresponding to a total of six current and future command and control situations were used for the estimates. The logic here is that with longer cuing delays the potential target movement area expands rapidly, while the proportion of the expanding target movement area that can be searched by NLOS decreases. The team used the paper and pencil search area estimates to raise the issue of target movement and NLOS search area coverage to Army Defense Simulation Network-Developmental (SIMNET-D) testers. The target movement issue was formally adopted for evaluation in the NLOS SIMNET-Developmental test, Phase I, which was conducted 1 through 17 April 1991, at Ft Rucker, Alabama.

Estimating target movement during NLOS engagements. NLOS capability to find rotary wing targets may be limited due the slow speed of the missile compared to target speeds and the time required to convey target information, launch the missile, and fly to the target area. The NLOS missile travels at a relatively low speed of approximately 100 meters per second (a 200 meters per second design has been explored), compared to a top speed of 320km/hr or 88 meters per second for the standard threat attack helicopter, the Mi-24 Hind. The Ft Bliss Directorate of Combat Developments estimated that target information sent through six current and future command and control systems would take from 0

seconds (NCTR sensor) to 160 seconds (Combined Arms [CA] Voice Net) to reach the NLOS fire unit (see Figure 8). Missile launch would require 30 seconds, and a 10km missile flight to a target area would require another 100 seconds, so that engagement times against a 10km distant target would range from 130 to 290 seconds. Figure 9 shows how far a target moving at 5 meters/second (hovering), 40 meters/second (half speed), and 80 meters/second (full speed) could travel during the six engagement times. For example, a target moving at 80 meters/second could travel 10.4 kilometers during a 130 second (NLOS with on-board sensor) engagement.

Proportion of target movement area searchable by NLOS.

Given estimates of the distance that a target can travel during an NLOS engagement before being overtaken by the missile, one can calculate the area in which the target can move and the proportion of this target area that can be covered by the NLOS missile's 2km wide seeker field of view. The proportion of a potential target area that can be searched by NLOS was estimated based on the distance a target can travel during an engagement, and the area that can be searched by the NLOS missile seeker using a formula that takes into consideration target cuing delay, missile speed, and target speed variables. For purposes of estimation it was assumed that a target would only move away from, or parallel to, the NLOS fire unit, so that the potential target movement area is represented by a half-circle.

The Percentage of Target Area Searchable (PTAS) by the NLOS missile can be estimated for a 100m/sec missile, with a 65 second (Manual SHORAD Control System (MSCS)) cue delay, 30 second launch time, and 100 second flyout time (195 seconds total until missile reaches target area) against a 10km distant rotary wing target moving 40m/sec as follows:

Given:

a = Time for target cuing, missile launch, and flight to target area (in seconds)

b = Missile Speed (in meters per second)

c = Target Speed (in meters per second)

FOV = Missile seeker Field Of View (2km wide)

$$1. \quad \text{Target Distance Traveled (TDT)} = \frac{(a \times c)}{(b - c)} \times b$$

$$\text{TDT} = \frac{(65 + 30 + 100 \text{ sec}) \times 40 \text{ m/sec}}{(100 \text{ m/sec} - 40 \text{ m/sec})} \times 100 \text{ m/sec} = 13\text{km}$$

Time From Target Detection Till Missile Reaches 10km Target Area

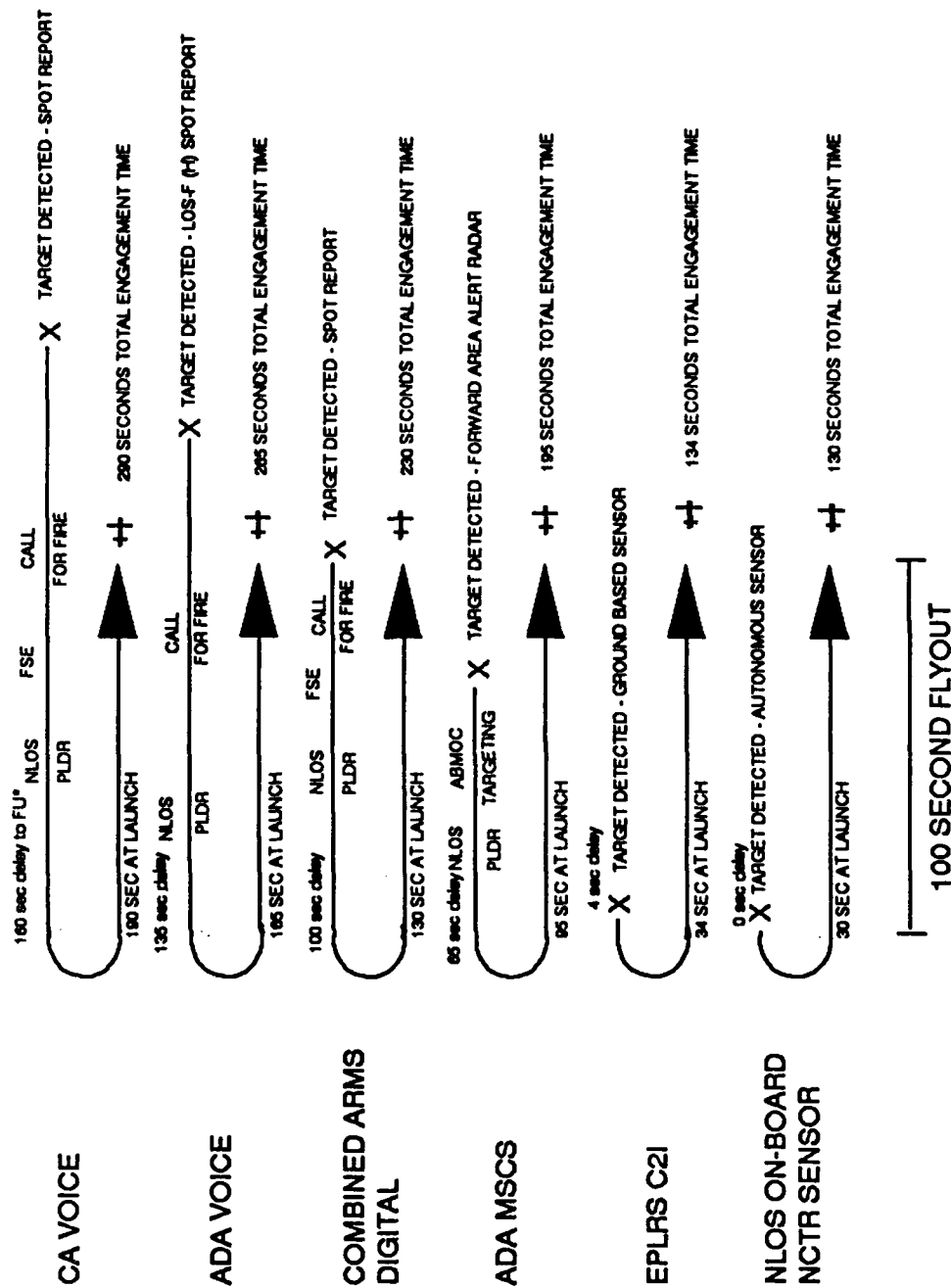
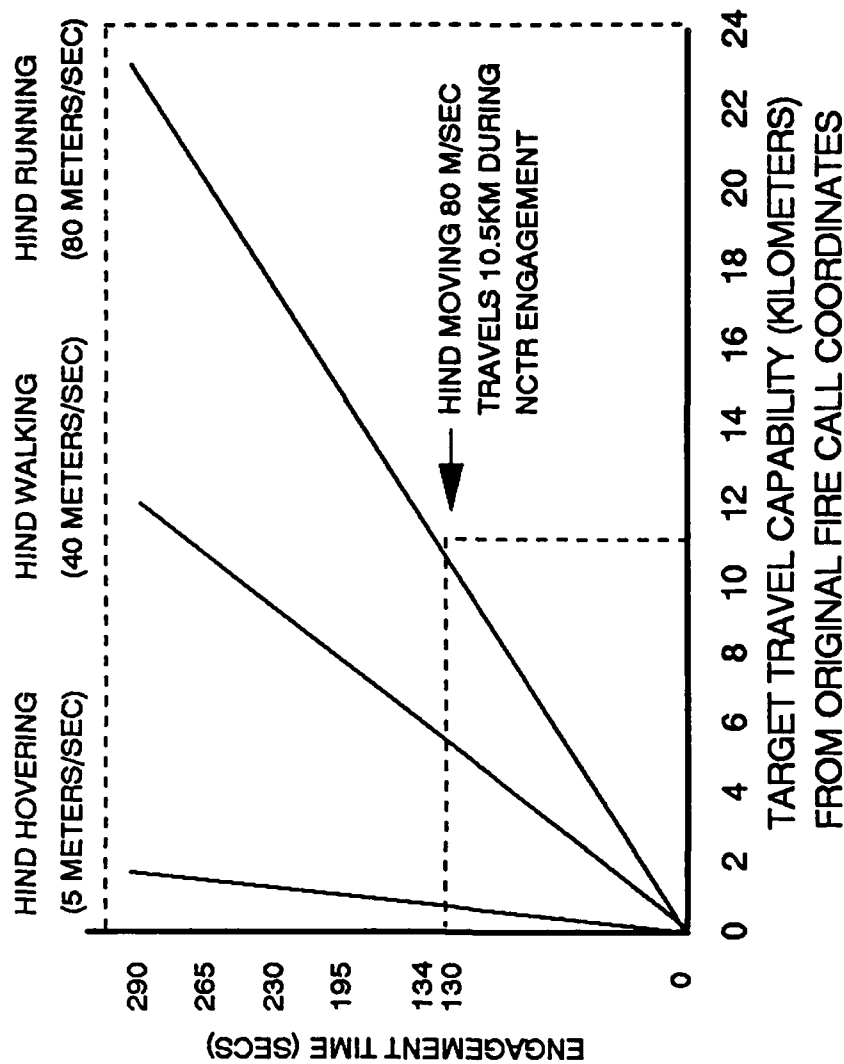


Figure 8. Engagement event timelines for six command and control methods.

CURRENT CALL TYPE	ENGAGEMENT TIME (SECS)*
CA VOICE	290
ADA VOICE	265
CA DIGITAL	230
ADA MSCS	195

FUTURE CALL TYPES	ENGAGEMENT TIME (SECS)*
EPLRS C2I	134
NLOS NCTR SENSOR	130



*SOURCE: DCD 22 JUNE 88 SLIDE "FIRING SEQUENCE TIMELINES" (JOE 100M/SEC MISSILE)
(A 200M/SEC MISSILE REDUCES TIMES APPROXIMATELY 25 SECONDS)

Figure 9. Target travel capability at three speeds during a 10km engagement under six NLOS command and control systems.

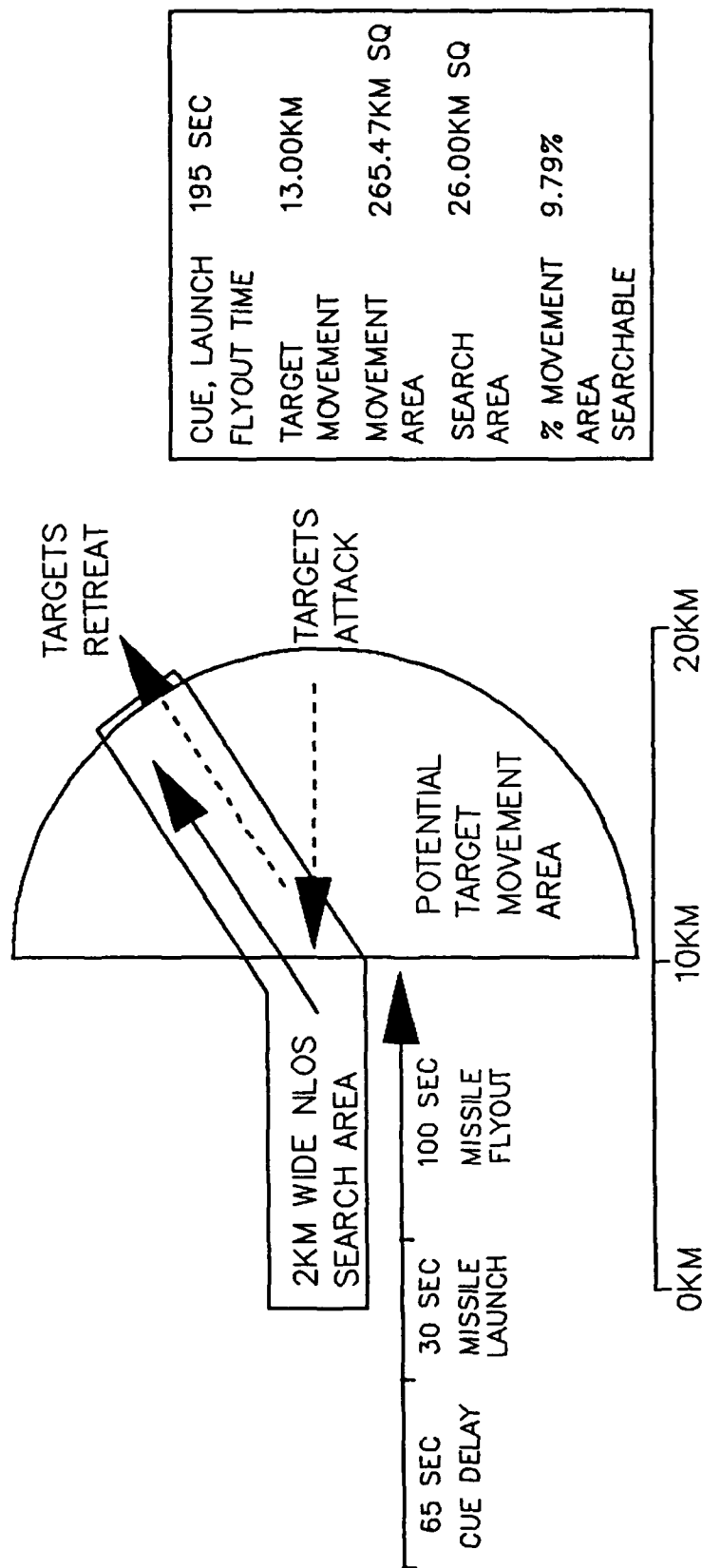
2. Target Movement Area (TMA) = $TDT^2 \times (3.1416 / 2)$
 $TMA = 13km^2 \times (3.1416 / 2) = 265.47km \text{ sq}$
3. Missile Seeker Search Area (MSSA) = $FOV \times TDT$
 $MSSA = 2km \times 13km = 26km \text{ sq}$
4. Percentage of Target Area Searchable (PTAS) = $TMA / MSSA$
 $PTAS = 265.47km \text{ sq} / 26km \text{ sq} = 9.79\%$

For the MSCS based engagement example presented above, it would take 195 seconds from target cuing initiation until the missile reaches the target coordinates at 10km distance. The target would be able to move up to 13km in any direction prior to being overtaken by the missile. The potential movement area beyond the target's initial position would be 265km sq, 9.79% of which could be searched by the NLOS missile seeker. A graphic representation of this target engagement example is presented as Figure 10. The probability of bringing targets into the seeker field of view should rise above the 9.79% estimate based on random missile search after reaching the original target coordinates, if target movement can be predicted and a target intercept course implemented. The NLOS gunner would use his knowledge of how geography and tactics constrain the movements of targets (Intelligence Preparation of the Battlefield), and any available target information to anticipate target movement.

SIMNET-D Target Movement and Target Acquisition Evaluation

One of the major user test issues for the NLOS SIMNET-D evaluation was provided by the Crew Weapons Performance Team. The test issue examined the effect of cue delay on target availability, specifically, whether command and control information delays and other target engagement time requirements would allow threat rotary wing aircraft to leave a searchable target area before the NLOS missile could arrive. Previous NLOS live fire and simulated engagement testing could not address this target availability issue because the cost of testing made it necessary that a target always be available for engagement in the target area. The cost constraint thus eliminated this important command and control element from NLOS operational testing. Through a series of briefings addressing command and control cuing delay and target movement issues, the team was able to have this key issue incorporated in the NLOS SIMNET-D evaluation.

SIMNET-D provided a computer generated virtual battlefield environment for NLOS target engagement assessments which included terrain views, friendly and hostile forces, and individual weapons systems status and location reports. The SIMNET-D



TARGETS RETREATING AT 40M/SEC WOULD BE INTERCEPTED 13KM FROM INITIAL SIGHTING COORDINATES AND 23KM FROM THE NLOS LAUNCH SITE

Figure 10. Target movement and percentage of movement area searchable by NLOS for a 10km Manual SHORAD Control System (MSCS) engagement.

simulators were realistic mock-ups of the objective NLOS weapon system and were operated by military personnel familiar with the system. The SIMNET-D NLOS fire units were cued on rotary wing and armor target positions and were cleared to launch missiles. Rotary wing tactics included hovering, pop-up, and transiting maneuvers.

For the NLOS SIMNET-D test, revised cue delay values were used to represent target cuing delays for automatic and manual systems. Rotary wing targets were presented to gunners with cue delays of 4, 15, 40 seconds (automatic cuing), and 15, 40, 85, 140, 190 seconds (manual cuing). Gunners were given target type, speed, and direction of travel which allowed them to roughly estimate a missile flight course to follow to intercept the targets. The SIMNET-D report (Wyant, 1991) presents results indicating whether targets were available for detection and engagement at the end of missile flyout for each of the six cue delay conditions. Unfortunately, the SIMNET-D Test Report does not present target availability results as a function of target speed and distance, which would be needed for a direct comparison to a calculated PTAS value. SIMNET-D results were that, overall, rotary wing targets were available to gunners on 377 of 640 trials (59%), so that on over 40% of all trials the target had left the search area of the missile prior to its arrival. These results confirm the importance of the target cuing delay and target movement issues.

A more detailed account of the impact of specific cuing delay times on SIMNET rotary wing target availability is presented in Figure 11 (Wyant, 1991). As would be expected, lengthening the cue delay decreased the probability that a target was available when the missile reached the cued target area. Given a future FAAD C2I system capable of conveying a cuing message to the correct NLOS Fire Unit with only a 4 second delay, SIMNET-D results indicate that there was a 95% probability that the target would be available in the missile seeker field of view when it arrived at the target area. For engagements conducted with the longer 85 second cue delay, more typical of the Army's current Manual SHORAD Control System (MSCS), targets fell within the missile search path on 50% of the trials. A longer cuing delay of 190 seconds, associated with the proposed use of the Combined Arms communications network, left targets within the missile search path on only 20% of the trials.

Conclusions: Target Cuing Delays and NLOS Target Acquisition

One ARI contribution to NLOS research and development has been the identification of the command and control target cuing delay as a key factor limiting NLOS target engagement capabilities. The MANPRINT evaluation of this issue yielded a quantitative estimate of the impact of command and control delays on one aspect of NLOS target acquisition performance. The potential impact of target cuing delays was initially identified from a simple paper and pencil analysis. The formula developed

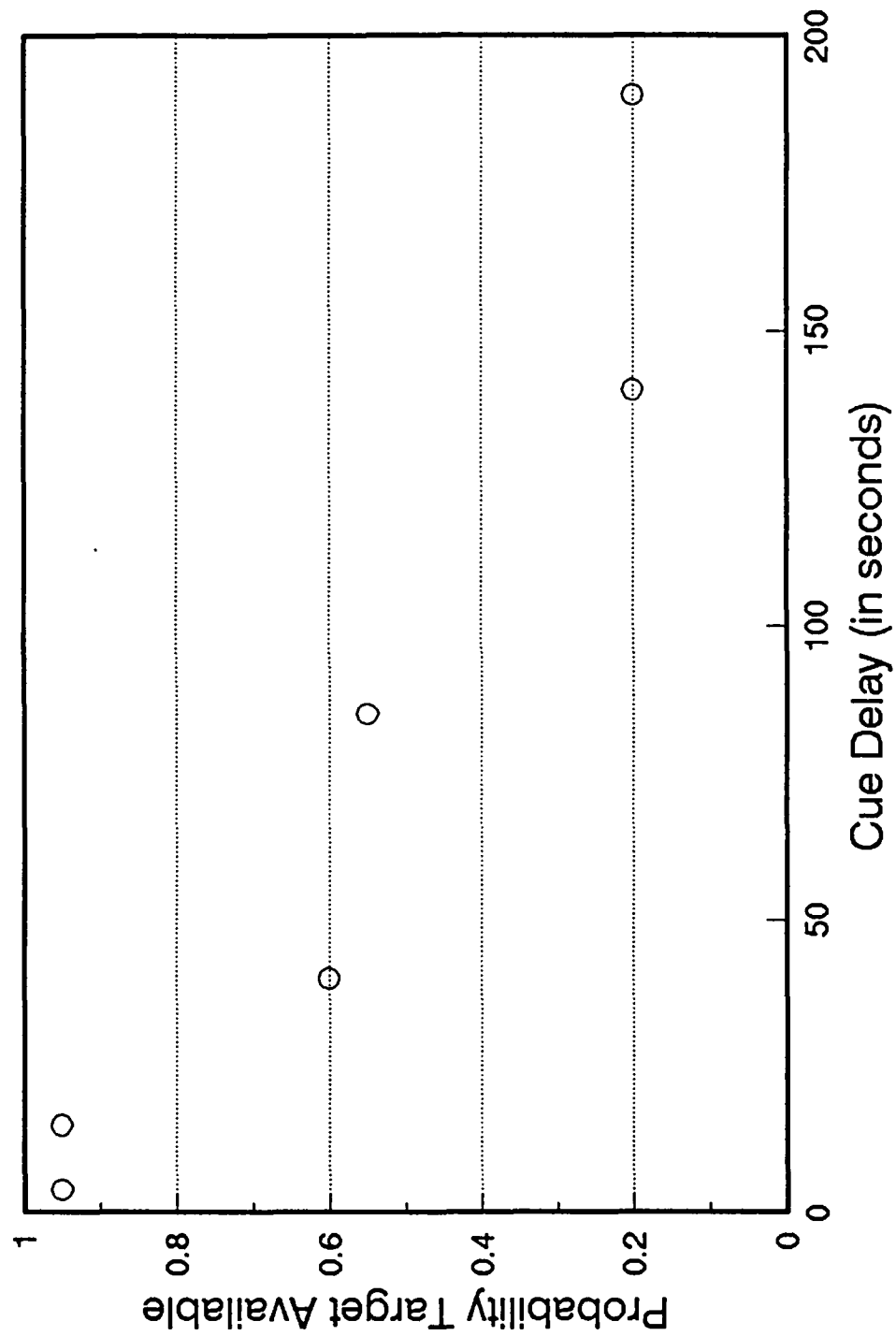


Figure 11. SIMNET-D command and control cue delays and target availability.

by ARI provided a quantitative estimate of the missile's target area search capability for six command and control options. The formula simply estimates the proportion of the potential target movement area that can be covered by the NLOS seeker, and thus reflects the likelihood of finding a target within its potential movement area by chance. The command and control delay issue was integrated into the SIMNET-D testing in order to validate the concern from within the formal NLOS acquisition program.

The extent to which the NLOS seeker can cover a target area is a key MANPRINT concern because as the system capability is reduced by cuing delays, the task of finding targets should depend increasingly on the skills and abilities of the Gunner. Knowledge of target direction of travel and speed should enable an NLOS Gunner to effectively reduce the potential target movement area and increase the likelihood of NLOS target acquisition above the "chance" target acquisition estimate. The paper and pencil target acquisition estimates produced in this effort provide one source of quantitative information that can serve as a basis for estimating how great a demand will be placed on Gunner skills to predict target movement and intercept coordinates for successful target engagements for six command and control options.

Conclusions

The goal of the NLOS MANPRINT support effort was to develop and apply concepts, methods, and tools for the evaluation of MANPRINT concerns to support the research and development program of the NLOS system. The broad objectives of this effort were threefold:

1. Provide or develop user-level methods for human factors evaluation, from source selection through fielding.
2. Develop effective strategies for integrating MANPRINT information and requirements into the weapon procurement process.
3. Demonstrate MANPRINT potential for improvements to force readiness, system operational availability, fire unit probability of kill, weapon system design, and the optimization of manpower, personnel, and training resources.

Usability research from the field of human-computer interface design has produced design evaluation guidelines and recommendations that were useful in deciding on an approach to the NLOS MANPRINT evaluation. Booth and Marshall (1989) identified the utility of collecting qualitative data in the design development stage that could suggest design changes to developers, while Whiteside, Bennett, and Holtzblatt (1988) and Landauer (1991) stress the need to examine system performance from the user perspective in a realistic task environment.

Carroll and Rosson (1985) argue for the use of mock-ups of equipment early in development to facilitate the generation of design ideas, while Virzi (1992) has found that even small numbers of representative users will be able to identify the majority of design problems from early hands-on design reviews.

A number of MANPRINT issue evaluations were conducted for the NLOS pre-production system by the Army Research Institute (ARI) Fort Bliss Crew Weapons Performance Team. Within the NLOS Force Development Test and Experimentation (FDTE) evaluation, the Performance Team examined soldier task performance and surveyed human factors issues of system design. For the Extended User Employment (EUE), the Performance Team carried out a series of low cost evaluations using the pre-production system and equipment mock-ups. For the NLOS Defense Simulation Network-Developmental (SIMNET-D) evaluation, the Task Force used a paper and pencil analysis to raise the issue of NLOS engagement effectiveness given target cuing time delays inherent in the required command and control system.

Results from MANPRINT evaluations support each of the three major objectives:

Objective 1: Provide or develop user-level methods for MANPRINT evaluation from source selection through fielding. The NLOS FDTE MANPRINT effort refined the MANPRINT performance error coding scheme, narrowing the scope of error scoring to enhance reliability while still meeting the information needs of the test-fix-test program. A human factors evaluation framework directly linked to the MIL STD 1472 Human Factors Engineering (HFE) Guidelines was introduced, which provided a systematic and comprehensive framework for evaluation that was used throughout the follow-on NLOS evaluations. The issue of operator workload was evaluated using a simple field data collection method. EUE was conducted as a series of separate low cost follow-up evaluations of lessons learned from NLOS FDTE and of proposed design changes. EUE MANPRINT evaluations supported decision maker information needs prior to the NLOS Critical Design Review. Issues identified for evaluation were the Gunner's Console design, crew emergency egress, the Embedded Trainer, crew drill night performance, and the vehicle light signature.

Objective 2: Develop effective strategies for integrating MANPRINT information and requirements into the weapons procurement process. ARI chaired the Manpower, Personnel, and Training Sub-Group of the NLOS System MANPRINT Joint Working Group (MJWG), integrating SMMP issues with the NLOS FDTE test plans. ARI assisted in preparing and executing FDTE test plans, participated in all aspects of field data collection and data analysis, and co-authored the final NLOS FDTE Test Report. ARI personnel integrated MANPRINT information and requirements into the NLOS weapons procurement process by serving on the NLOS Source Selection and Evaluation Board. The results of the

several EUE MANPRINT evaluations were distributed as formal memoranda through the NLOS TRADOC System Manager to the NLOS Program Manager, the NLOS Human Engineering Working Group, the NLOS System Safety Working Group, equipment developers, and other agencies involved in NLOS development.

Objective 3: Demonstrate MANPRINT potential for improvements to force readiness, system operational availability, fire unit probability of kill, and manpower, personnel, training, and weapons system design. The MANPRINT effort was directed in part toward identifying both the nature and the cause of human performance errors, so that remedies might be found to reduce these errors. The potential for MANPRINT contribution to improved force readiness through error assessment can be estimated through some simple calculations. As example, in NLOS FDTE a six percent error rate for Launch Control tasks was identified. Program plans called for the acquisition of 16,050 missiles at a cost of roughly \$50,000 each. If Launch Control errors lead to mission failure then the six percent figure could translate into a wastage of 963 missiles, at a cost of \$48,150,000. If these Launch Control errors could be reduced by 50% through training or redesign, a cost savings of \$24,075,000 might be realized.

The EUE MANPRINT effort demonstrated the ability of the MANPRINT approach to influence the design of new systems. Concerns regarding the overcrowding of the crew compartment and related safety issues led to the relocation of some equipment items to enhance operator safety. The NLOS SIMNET-D effort demonstrated the ability of the MANPRINT program to isolate and address key issues of system operational effectiveness. The simple NLOS target movement and search area estimates were of sufficient power to raise the target search issue to the level of a formal test issue for the NLOS SIMNET-D evaluation. The concern that target cueing delays inherent in the required target cueing command and control systems could greatly reduce NLOS engagement effectiveness was supported by the SIMNET-D test data for target detection.

REFERENCES

- Booth, P., & Marshall, C. J. (1989). Usability in human-computer interaction. In Booth, An introduction to human-computer interaction (pp. 103-136). London: LEA.
- Byers, J. C., Bittner, A. C., Jr., & Hill, S. G. (1989). Traditional and raw Task Load Index (TLX) correlations: Are paired comparisons necessary? In A. Mital (Ed.), Advances in industrial ergonomics and safety I (pp. 481-485). London: Taylor & Francis.
- Carroll, J. M., & Rosson, M. B. (1985). Usability specifications as a tool in interactive development. In H. R. Hartson (Ed.), Advances in human-computer interaction (pp. 1-28). Norwood, New Jersey: Ablex.
- Department of the Army. (1990). Manpower and Personnel Integration (MANPRINT) in the materiel acquisition process (AR 602-2). Washington, DC: Headquarters, Department of the Army.
- Landauer, T. K. (1991). Let's get real: A position paper on the role of cognitive psychology in the design of humanly useful and usable systems. In J. M. Carol (Ed.), Designing Interaction (pp. 60-73). Cambridge: Cambridge University Press.
- Matthews, L., Keaton, J., Jolly, M., Lewis, L., Sanders, W., & Griffith, E. (1989). Force Development Test and Experimentation (FDTE) of the Forward Area Air Defense (FAAD) Non-Line-Of-Sight (NLOS) [Fiber-Optic Guided Missile (FOG-M)] system. Fort Bliss, TX: U.S. Army Test and Experimentation Command, Air Defense Artillery Board.
- NASA-Ames Research Center, Human Performance Group. (1986). Collecting NASA workload ratings: A paper and pencil package (Version 2.1). Moffet Field, CA: NASA-Ames Research Center.
- Purifoy, G. R., Ditzian, J. L., & Finley, D. L. (1989). Implementing Embedded Training (ET): Volume 7 of 10: Embedded training test and evaluation (ARI Research Product 89-02). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A207 290)
- Sanders, W. R. (1990). NLOS EUE gunner console design mock-up evaluation. Memorandum for NLOS TRADOC System Manager dated 23 February, 1990. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Bliss Field Unit.

- Sanders, W. R. (1990). NLOS EUE crewmember egress evaluation. Memorandum for NLOS TRADOC System Manager dated 30 August, 1990. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Bliss Field Unit.
- Sanders, W. R. (1991). NLOS embedded trainer MANPRINT evaluation. Memorandum for NLOS TRADOC System Manager dated 22 February, 1991. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Bliss Field Unit.
- Sanders, W. R. (1990). NLOS EUE task illumination MANPRINT evaluation. Memorandum for NLOS TRADOC System Manager dated 10 December, 1990. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Bliss Field Unit.
- U.S. Army Air Defense Artillery School. (1987). Capstone required operational capabilities for the Forward Area Air Defense (FAAD) system, annex I--NLOS Component. Fort Bliss, TX.
- U.S. Army Missile Command. (1989). Human engineering design criteria for military systems, equipment and facilities (Army MIL STD 1472 D). Redstone Arsenal, AL: U.S. Army Missile Command.
- U.S. Army Test and Evaluation Command. (1983). TECOM Human Factors Engineering Guidelines and Human Factors Engineering Data Guide for Evaluation (HEDGE) (Test Operations Procedure 1-2-610, parts 1 and 2). Aberdeen Proving Ground, Maryland.
- U.S. Army Test and Evaluation Command. (1985). TECOM soldier-computer interface guidelines (Test Operations Procedure 1-1-059). Aberdeen Proving Ground, Maryland.
- Virzi, R. A. (1992). Refining the test phase of usability evaluation: How many subjects is enough? Human Factors, 34(4), 457-468.
- Whiteside, J., Bennett, J., & Holtzblatt, K. (1988). Usability engineering: Our experience and evolution. In M. Helander (Ed.), Handbook of Human-Computer Interaction (pp. 791-817). Amsterdam: North-Holland.
- Wyant, K. W. (1991). Independent operational assessment of the non-line-of-sight simulator and the defense simulation network as user testing tools (OA-1394). Alexandria, VA: U.S. Army Operational Test and Evaluation Command.

APPENDIX A

NLOS EUE GUNNER CONSOLE DESIGN EVALUATION

DEPARTMENT OF THE ARMY
U.S. Army Research Institute for the Behavioral and Social Sciences
Fort Bliss Field Unit, P.O. Box 6057
Fort Bliss, Texas 79906-0057

PERI-SB (701n)

23 February 1990

MEMORANDUM THROUGH DIR, ARI FAAD MANPRINT TASK FORCE (ATTN: DR DEPONTBRIAND)

TO: TRADOC SYSTEM MANAGER, ATSA-TSM-F, ATTN: MAJ FEDAKO

SUBJECT: NLOS EUE GUNNER CONSOLE DESIGN MOCK-UP EVALUATION

1. Purpose: Have NLOS gunners and other members of the NLOS community make an initial hands-on review of the proposed Boeing gunner console design at least thirty days prior to an anticipated 15 March NLOS Critical Design Review, to explore whether the gunner's console physical dimensions and location might impact required task performance and system safety requirements.

2. Method: Three mock-ups of the Boeing gunner console design were built and used in hands-on evaluations by gunners on 16 and 19 February 1990 at Ft Bliss. Each mock-up includes three rectangular boxes measuring 12 X 5 X 8.75 inches, 8 X 11.23 X 10 inches, and 12 X 5 X 5 inches, generally meeting the dimensions presented in the updated diagram "Gunner's Console Design Concept (Dimensional)" provided as enclosure 1.. Paper representation of switches and buttons were attached to box faces consistent with the "NLOS Gunner's Console" diagram provided as enclosure 2.

a. Sheet metal mock-ups of the gunner console and armrest controls were used for static evaluation. Photographs were taken of the NLOS workspace with gunners wearing Load Bearing Equipment (LBE) and MOPP 4 gear (see enclosure 3).

b. A Styrafoam and cardboard mock-up was used in road testing of the gunner console design at Training Area #30 (the dust bowl) at Ft Bliss. This soft gunners console was used to ensure that gunners would not be injured if they fell against the gunner console during off-road movement during hard breaking at 10 mph.

c. A three piece plywood mock-up of the separate gunner console components was used to allow gunners to explore various arrangements of the three components in a standard HMMWV and an NLOS IOE fire unit.

d. A four-door "command vehicle" HMMWV was used for static and mobile gunner console design evaluations, as it provided a conventional under dash heater/blower

equipment arrangement instead of the modified arrangement present in NLOS IOE fire units. The "command vehicle" HMMWV was fitted with SINCGARS equipment and a cloth partition was placed directly behind the front two seats to create the back wall and related space constraints present in the NLOS fire unit design.

- e. Soldiers were four experienced NLOS gunners ranging in height from 5'8" to 6'3".

3. Results:

- a. Photographs were obtained of gunners in the vehicle with the sheet metal mock-up for further review.

- b. The following observations were made while reviewing the sheet metal mock-up:

- Gunners can reach all the gunner console control switches on the proposed Boeing gunner console

- Gunners reported that the on-the-dashboard position of the gunner console screen provides an acceptable viewing angle

- Gunners and other members of the NLOS community commented that the right armrest and joystick might be broken or damaged, and that the joystick in particular might get "knocked around" and need recalibration. One gunner was observed to bend the armrest sideways as he moved about to adjust his seatbelt. The gunners and others said that the right armrest and joystick could be a maintenance problem due to a potential for damage and the trouble of tracking down armrest wiring related problems. Gunners and others recommended that we explore ways of integrating the joystick with the other components of the gunner console.

- Gunners wore LBE (with only one of the two canteens) with the armrests in the down position and reported that the gunners position was cramped and allowed for little movement. Gunners stated that wearing LBE in the gunners position is an artificial evaluation, as soldiers will remove their LBE and store it in the cab when the vehicle is moving.

- The on-the-dashboard location of the gunner's console blocks the drivers view of the right side vehicle rear view mirror and also partially blocks the drivers view of the ground near the right front of the vehicle.

- The on-the-dashboard location of the gunner's console might block the windshield defrost vent.

c. The following observations were made while reviewing the gunner console using the Styrafoam mock-up while driving over dirt roads at Training Area #30:

- The gunners did not hit against the gunner console screen during low speed movement over dirt roads with some bumps. Most gunners and others did bump the front of their hat brims directly against the gunners console screen under a hard breaking maneuver. The breaking maneuver involved moving at 10 mph on a level dirt road, announcing that breaking was to occur, and then hard breaking which did not necessarily lock up the vehicle tires.

- The two gunners about 5'8" tall reported that they couldn't see where they were going because the gunner's console was in the way. Comments were made that for daytime movement, the gunner's console digital map was an additional aid, and that the paper map was still the primary and most reliable source of information to the gunner. Gunners said that the gunner, not the driver, is responsible for using the paper map, and that they can't use the map if they can't see where they are going. Gunners said that both crew members needed to see for safe night movement. The gunner needs an unrestricted forward view.

- Gunners pointed out that soldiers may not be willing to wear a shoulder harness portion of a modified seat belt arrangement which Boeing has suggested as a means of restricting gunner forward movement into the gunner's console. The concern here is that provision of a modified restraint system may not be a sufficient measure to prevent accidents involving gunners impacting against the gunner console screen. This is similar to the observation that Gunners will likely not wear LBE during vehicle movement.

d. The following observations were made while reviewing the gunner's console using the three-piece plywood mock-up while stationary:

- The gunners stated that the positioning of the gunner console screen directly in front of the gunner on the dash was correct for conducting engagements but not as a land navigation aid during vehicle movement. Land navigation and night movement requires that the gunner be able to see out the windshield.

- The gunners did not like the idea of moving the gunner console screen under the dash similar to the NLOS IOE configuration.

- The gunners would like to see the two control pannels moved down and out of the window viewing area.

- The gunners stated that moving the gunner's console screen to a lower position directly in front of the gunner was desirable during vehicle movement. Gunners suggested that this might be accomplished using an "L" shaped bracket that would allow the screen to be pulled several inches toward the gunner and then down into a chest level position during vehicle movement.

- Alternately, the screen could be moved laterally toward the driver during vehicle movement. A rail mounting for the gunner's console similar to that used on the IOE NLOS fire unit might be adopted, allowing the gunner's console to slide one and a half feet to the left from a position directly in front of the gunner to a position out of his direct field of view through the windshield.

4. Summary

- The gunners stated that the positioning of the gunner console screen directly in front of the gunner on the dash was correct for conducting engagements, but not as a land navigation aid during vehicle movement. Land navigation and night movement requires that the gunner see out the windshield.

- A road test with the gunner's console mock-up suggests that gunners wearing lap seatbelts can be thrown into the console screen. The addition of an improved restraint system might alleviate this potential problem, if gunners can be expected to wear a shoulder harness for extended periods of time.

- Gunners did not like the idea of placing the gunner's console screen under the dash in a configuration similar to that of the current IOE systems.

- Gunners suggested that we look into mounting the gunner's console screen so that it can be moved down and out of the window area during vehicle movement, or sideways to the left during vehicle movement. Proximity of controls to displays is a valuable design feature, but safety concerns and a need for gunner forward vision may represent a higher priority.

- Armrests and their controls raised concerns regarding potential for damage and a resulting maintenance requirement.

5. Additional Army Research Institute concerns:


- Consider the implications of having a TV type screen mounted above dashboard level in a HMMWV in terms of night operations light discipline requirements.

- Consider the implications of a dashboard mounted TV type screen light source on the driver and gunner's night vision and driving ability.

- Boeing gunner's console design places the control box with the time critical data entry and engagement switches on the left side of the console, but most gunners are right handed. Would human performance be enhanced by moving the data entry box over to the right side of the console?

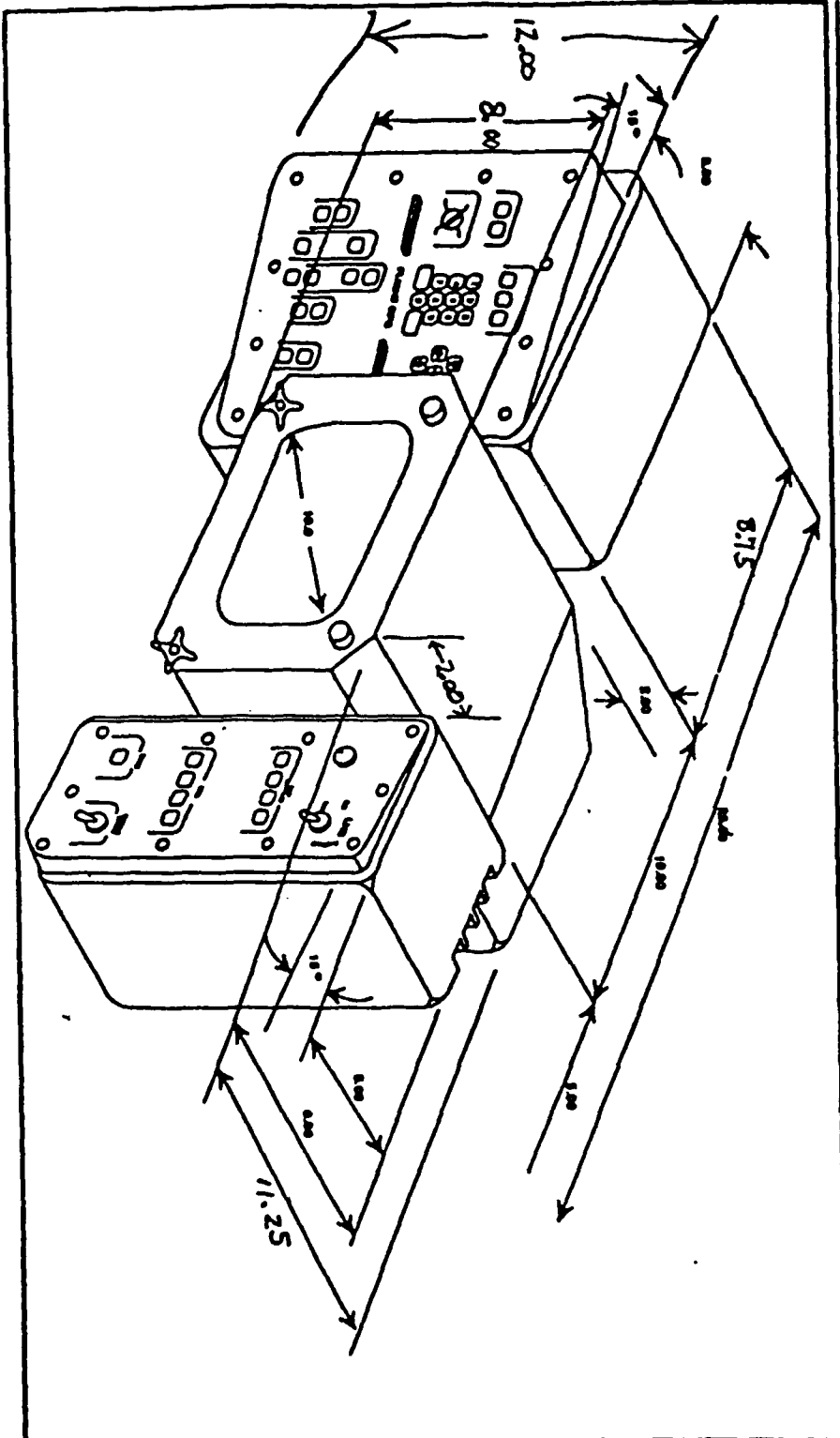
6. The POC for this action is Mr. Bill Sanders, AV978-4491/5297.

Encl
as


WILLIAM SANDERS
Research Psychologist

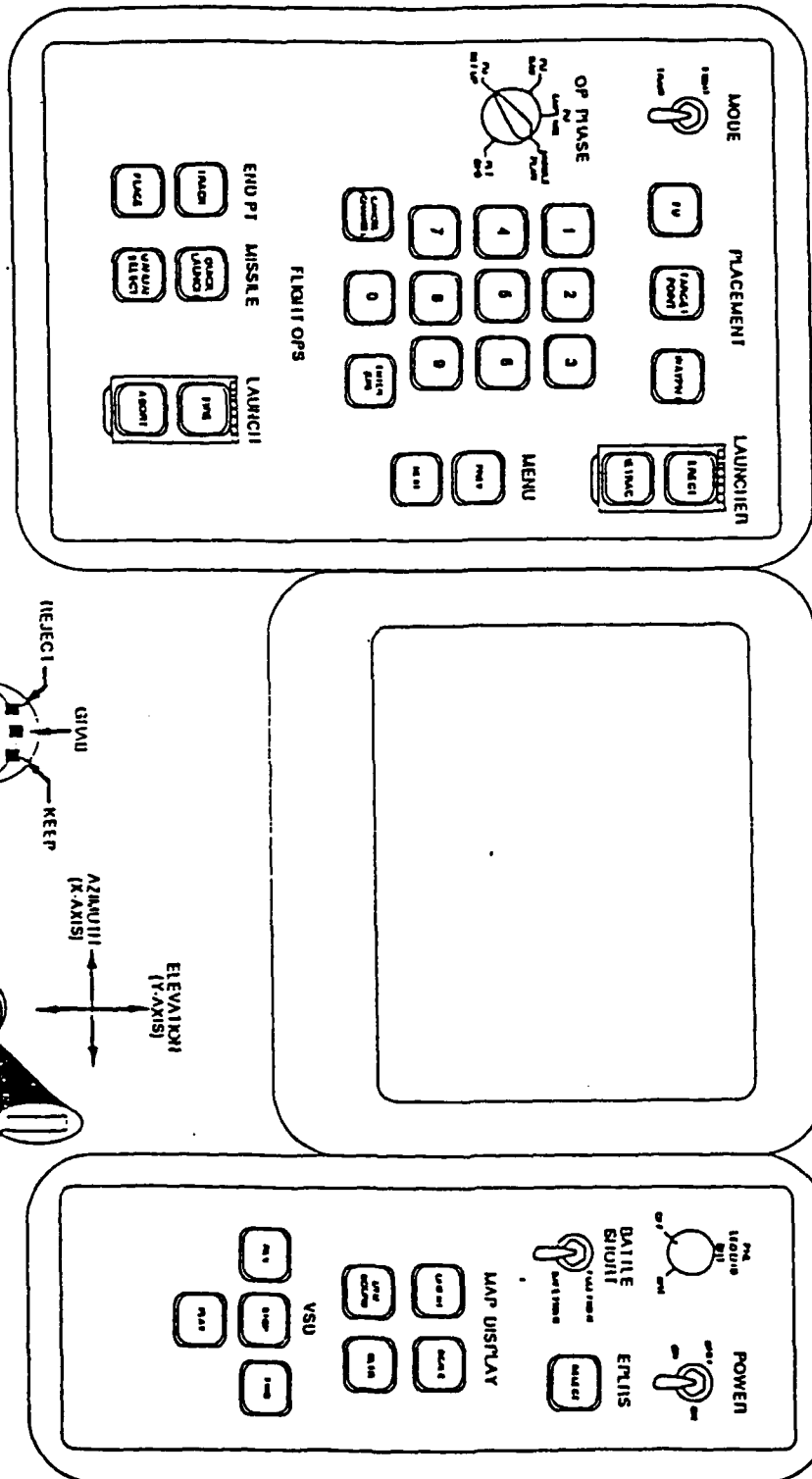
NLOS
FOG-M

GUNNERS CONSOLE DESIGN CONCEPT (DIMENSIONAL)



encl 1

NLOS GUNNER'S CONSOLE



LEFT HAND CONTROLLER

JOYSTICK

encl 2

ARI OBJECTIVE SYSTEM GUNNER'S CONSOLE MOCK-UP



encl 3

APPENDIX B

NLOS EUE CREWMEMBER EGRESS EVALUATION

DEPARTMENT OF THE ARMY
U.S. Army Research Institute for the Behavioral and Social Sciences
Fort Bliss Field Unit, P.O. Box 6057
Fort Bliss, Texas 79906-0057

PERI-SB-C

30 August 1990

**MEMORANDUM FOR DIR, TRADOC SYSTEM MANAGER, ATSA-TSM-F, ATTN:
MAJ FEDAKO**

SUBJECT: NLOS EUE CREWMEMBER EGRESS EVALUATION

1. Purpose

Conduct an evaluation to assess how the addition of equipment to the NLOS crew cab might impact the ability of both crewmembers to egress the vehicle, and identify key design features that facilitate or restrict egress performance. The proposed addition of several items of equipment to the crew cab of the NLOS fire unit raised Human Factors Engineering and System Safety MANPRINT concerns regarding the crewmembers ability to quickly exit the vehicle through a single door in the event of overturning, or a serious accident. No crewmember egress performance requirement has been established for NLOS, however Human Factors Engineering MIL STD 1472D provides some design standards.

2. Method

The evaluation was conducted by Army Research Institute Fort Bliss Field Unit within the framework of MANPRINT support to the NLOS Extended User Employment effort. Four NLOS gunners from A battery, 2nd Battalion, 6th ADA Brigade, were evaluated on their ability to egress from an NLOS fire unit. Performance information was recorded using a stop watch and videotape recordings. To simulate a vehicle turned on its side both crewmen, driver and gunner, were asked to exit through a single door. Crewmen were not allowed to assist each other in exiting the vehicle. Trials began with both crewmen wearing their seat belts. Crewmen exited the vehicle through the left door, and the right door, in both MOPP0 and MOPP4 daylight conditions.

a. **Trials Schedule:** The four gunners were divided into two teams. Each team completed trials in MOPP0 and MOPP4, first exiting through the right door, and then the left. Each gunner attempted four trials in each of the four conditions, Right MOPP4, Right MOPP0, Left MOPP4, Left MOPP0, for a total of sixteen trials per gunner, and sixty-four trials total. Team members rotated between driver and passenger positions after each trial. Teams rotated after completion of the sixteen trials in each condition.

b. **Equipment Mock-Ups:** Three mock-ups were built to represent key components of the proposed Boeing NLOS system which might impact crewmember egress performance, a Gunner's Console, Air Plenum Box, and Enhanced Handheld Terminal Unit. Components were installed in Fire Unit #1, with the original Gunner's Console removed and the overhead ventilation box and hoses removed to more closely resemble the objective NLOS configuration. The fire extinguisher was relocated 4" forward of original position between seats to allow for the placement of the Air Plenum Box.

1. **Gunner's Console:** The Full Scale Development (FSD) gunner's console mock-up was composed of three rectangular sheet metal boxes measuring 12 X 5 X 8.75 inches, 8 X 11.25 X 10 inches, and 12 X 5 X 5 inches, generally meeting the dimensions presented in the updated diagram "Gunner's Console Design Concept (Dimensional)" provided as enclosure 1.

2. **Air Plenum Box:** An Air Plenum box has been proposed for the FSD NLOS crew compartment to provide cooling air to the NLOS computer equipment. The box would be located between the crew compartment seats, fitting flush against the rear window of the compartment. The Air Plenum box mock-up was a rectangular plywood box measuring 24 X 25 X 10 inches, covered with fabric to reduce any surface snag potential.

3. **EHTU:** An Enhanced Hand-held Terminal Unit (EHTU) has been proposed for the NLOS system, and diagrams have shown this equipment mounted above other SINCGARS and Enhanced Position Location Reporting System (EPLRS) equipment. For this evaluation a 3 X 12 X 11.5 inch rectangular EHTU mock-up was constructed from a hard cover three ring binder capable of supporting the full weight of a soldier. The mock-up represented an EHTU with the screen lid in the closed position. The EHTU mock-up was secured in place on top of the NLOS radio rack with duct tape.

c. **Gunner's personal gear:** Each gunner wore BDU's, kevlar helmet, web gear, two canteens (empty) on a belt. For MOPP4 trials gunners wore MOPP4 overgarment, mask/hood, gloves, overboots, web gear, canteens on a belt. Gunners did not wear a flack jacket. MOPP4 trials for the two crewmen evaluated in the afternoon were modified so that the inner liner of the MOPP4 suit was not worn. The liner was not worn because it became saturated with moisture during early trials. Soldiers were allowed to remove MOPP4 gear between trials to cool off.

d. **Soldier demographics:** Crewmen ranged from 5'8" to 6'2.5" in height, and were all of light build ranging from 145 to 185 pounds in weight.

3. Results

a. **Available Passage Space:** With the Gunner's Console, Air Plenum, and EHTU mock-ups in place, the available passage space near the roof in the NLOS crew cab between the driver and gunner positions was approximately 12 - 13 inches high and 32

inches wide. However, roof support bars reduced the available passageway height to only 10-11 inches directly beneath these one inch wide supports. There was also an adjoining 6 inch wide and 30 inch high passageway open between the radio rack and the air plenum extending from the floor above the fire extinguisher to the roof (see enclosure 2). MIL STD 1472D section 5.7.8.3 (Whole-body access) states that dimensions for rectangular access openings for body passage of soldiers in light clothing shall not be less than 26 inches high and 30 inches wide, and for bulky clothing not less than 29 inches high and 34 inches wide, and that diameters of oval hatches in armored vehicles shall not be less than 17 inches by 28 inches (see enclosure 3).

b. Time Data Analysis Summary: Times required for gunners to egress from the stationary vehicle, from a "seat belt on" position to the time the gunner had both feet on the ground and body fully outside the vehicle are summarized below:

- MOPP0 times (in seconds)

- Left side egress

Mean: 14.41
Minimum: 7.67
Maximum: 22.32

- Right side egress

Mean: 12.96
Minimum: 5.98
Maximum: 24.81 (2 hang-ups omitted)

- MOPP4 times (in seconds)

- Left side egress

Mean: 12.22
Minimum: 9.10
Maximum: 17.37

- Right side egress

Mean: 15.61
Minimum: 8.04
Maximum: 27.64 (3 hang-ups omitted)

Mean performance time across 59 trials: 13.74 seconds

c. Observations

1. Use of IOE NLOS overhead roof support bars as hand-holds: The NLOS IOE systems have a canvas roof with a one-inch foam rubber covered roof support bar running centrally from the roof above the drivers side door to the roof above the passenger side door. Two one-inch roof support bars run in parallel, six inches apart, centrally from the front edge to the back of the roof, as shown previously in Enclosure 2. The canvas roof above these bars is flexible so that soldiers can close their hands around the bar to grasp it and pull themselves out of the vehicle. It was found that these roof support bars were used extensively as an assist to gunner egress. The first attempt by a gunner to crawl "belly down" over the radio equipment rack resulted in a great deal of struggling and effort and an egress time of about one minute. After seeing this trial another gunner adopted the technique of inverting himself "belly up" and using the overhead support bars as hand holds to pull himself over the radio rack until he could reach out and grab the edge of the roof above the open doorway. This successful technique of using the overhead support bars as handholds was adopted by all four gunners for subsequent trials, unless they were told to try the "belly down" technique by the evaluators.

2. Radio rack to Air Plenum passage way use: A six-inch wide and thirty-inch tall passage way existed between the Air Plenum and the radio rack which was very useful to gunners as they exited the vehicle. The passageway is partially obstructed by the wiring cables protruding from the face of the SINCGARS radios toward the Air Plenum. This passageway between the two large equipment structures was used by gunners during egress to drag one leg through beneath their body, both to push against the floor and support their body weight as they moved over the radio equipment, and also to support their body once they had cleared the radio rack and needed to swing out of the vehicle.

3. IOE system soft canvas roof: The soft "canvas" type roof played a role in the egress tasks. It was clearly visible that the canvas roof was being pushed up as gunners worked to crawl through the narrow passage way space between crew compartment Air Plenum and radio rack equipment and the roof.

4. Gunners adopted the practice of removing their helmets and throwing them over the radio equipment rack prior to attempting egress.

5. Performance times for five trials were not included in summary statistics because of complete egress failure, or where soldier personal gear became entangled on NLOS equipment. Observations for these five trials are detailed below:

6. Trial 1a: On the first trial the gunner attempted a "belly down" crawl over the radio rack equipment. The gunner searched for handholds to use to support his weight and to use in pulling himself over the equipment. The soldier tried to egress with his helmet on. The gunner succeeded in exiting after 56.94 seconds.

7. Trial 7a: The soldier became stuck and was not able to egress. The gunner got caught in the space between the radio rack and the Air Plenum. He squeezed his body along the front of the air plenum but the equipment at his waist pushed directly up against the drivers side of the air plenum and would not allow him to pull through.

8. Trial 8b: The soldier became "hung-up" as the ammunition pouch on the right side of his body became entangled on the windshield wiper box knob. The gunner was egressing in a belly-up position and had his right hand firmly grasping the passenger side roof edge when his equipment became entangled. The gunner was unable to pull his equipment off the wiper box switch with his free left hand. The gunner moved back into the vehicle, freed the gear with his right hand, and exited the vehicle without assistance after a total of 35.13 seconds.

9. Trial 9a: The soldier became "hung-up" when his web gear became entangled with equipment. The gunner successfully egressed from the vehicle without assistance after 46.43 seconds. No video of this trial.

10. Trial 19a: The gunner tried to egress in a belly-down position with his helmet on. He retreated backwards to remove his helmet, and again tried a belly-down egress while trying to hold his loose personal gear close to his body. The personal gear got caught on equipment, and the soldier retreated backwards and attempted a belly-up egress. He experienced difficulty again, returned to the starting position in the drivers seat, and announced "I'm dead" after 38.24 seconds time had elapsed. The gunner felt he could do much better and wanted to end this trial when it was clear he could not egress quickly. In his next two trials he egressed successfully in ten seconds or less.

11. Gunner performance motivation: Gunners displayed a high level of motivation to achieve low egress performance times during the trials. An informal competition occurred between the gunners to achieve the lowest time.

12. Force exerted on equipment mock-ups: The gunners exerted a great deal of force on some equipment mock-ups during their efforts to egress from the NLOS system. The GC mock-up was knocked sideways off the dashboard of the vehicle and had to be re-secured with additional duck tape. The plastic screen on the GC was broken off during an early trial. The gunners stepped on the fire extinguisher during egress and moved it around within its fixture. The EHTU mock-up had to be re-secured with additional duck tape during the course of the trials as a great deal of force was exerted as the gunners pulled themselves over this equipment and out of the vehicle.

4. Summary

a. Egress was evaluated because the proposed addition of several items of equipment to the crew cab of the NLOS fire unit raised the concern that the crewmembers ability to quickly exit the vehicle might be restricted.

b. No specific crewmember egress performance requirement had been specified for NLOS, however MIL STD 1472D (Whole-body access) provides related design standards. The NLOS IOE system with equipment mock-ups installed offered an approximately 11 inch by 32 inch radio rack to roof passage way for egress. This passage way was considerably smaller than the MIL STD 1472D recommendation of 29 inches by 34 inches for crewmembers wearing bulky clothing.

c. The gunners were able to egress over the radio equipment rack from both sides of the vehicle, in both MOPP0 and MOPP4. No differences appear between MOPP0 and MOPP4 performance times, or between left and right side egress times. Mean egress time across 59 successful trials was 13.74 seconds. Egress failures or extreme times occurred on five trials which were not included in overall time computations.

d. Gunners most frequently used the roof support rails to pull themselves upside down over the radio rack. However, gunners also were successful using an "arms first" belly crawling maneuver to get over the radio rack to egress from the vehicle, so that the roof rails were not absolutely essential for successful egress.

e. Gunners made use of the available passageway space between the SINCGARS radio rack and the Air Plenum Box. Any Full Scale Development design should consider the utility of preserving this six inch passageway as a minimum to facilitate emergency egress.

f. Gunner egress time trends suggest that knowledge of an effective approach to egress and practice can greatly reduce egress times.

5. Additional Concerns

a. The close (6 inch) proximity of the Air Plenum Box facing the SINCGARS radios made reading the SINCGARS displays difficult, and could prevent the removal of the SINCGARS from the current IOE radio rack. SINCGARS display visibility and removal requirements need to be incorporated into the Full Scale Development system design.

b. Several weeks after the evaluation an NLOS gunner stated that crewmembers would also normally be required to wear flack jackets in an operational environment. Flack jackets were not worn during the egress evaluation. The addition of a flack jacket to personal gear worn by the gunners could make egress a much more difficult task and significantly increase performance times. Egress from the vehicle might not have been possible if gunners were wearing flack jackets. Removal of flack jackets would require some time in the cramped crew compartment.

c. A hardtop version of the NLOS would not provide the overhead bars used extensively by soldiers to pull themselves out of the vehicle, and would not provide the flexible roof characteristic that allowed the roof to be raised several inches so that

gunners had additional room to squeeze over the equipment. Egress performance could be significantly worse if the soft top were simply replaced with a hard top with other equipment remaining the same.

6. Preliminary results of this evaluation were presented at the NLOS Human Factors Engineering Working Group meeting held at the Boeing Huntsville facility on 4 June 1990.

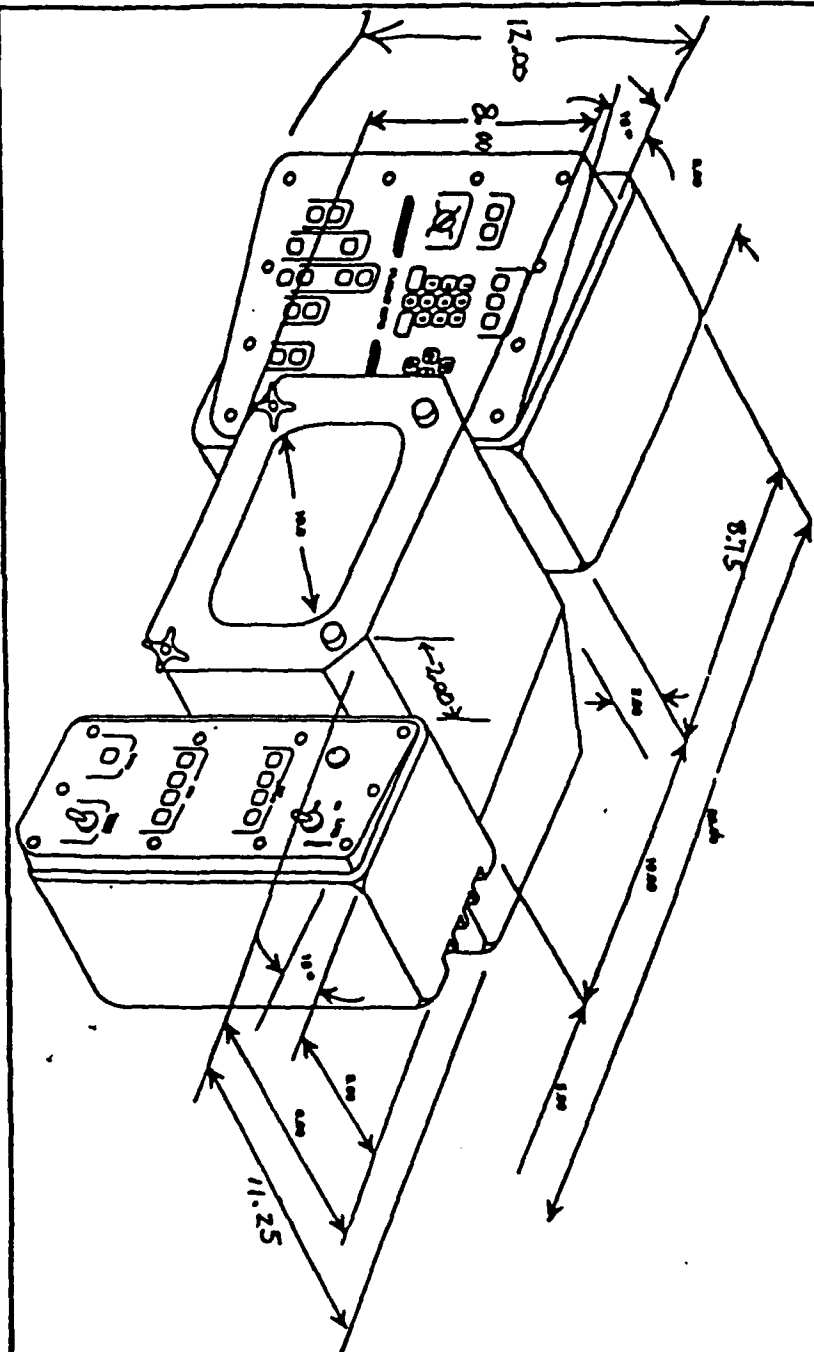
7. The POC for this action is Mr. William Sanders or Mr. Don Carter, AV978-4491/5297.

Encl
as


WILLIAM SANDERS
Research Psychologist

NLOS
FOG-M

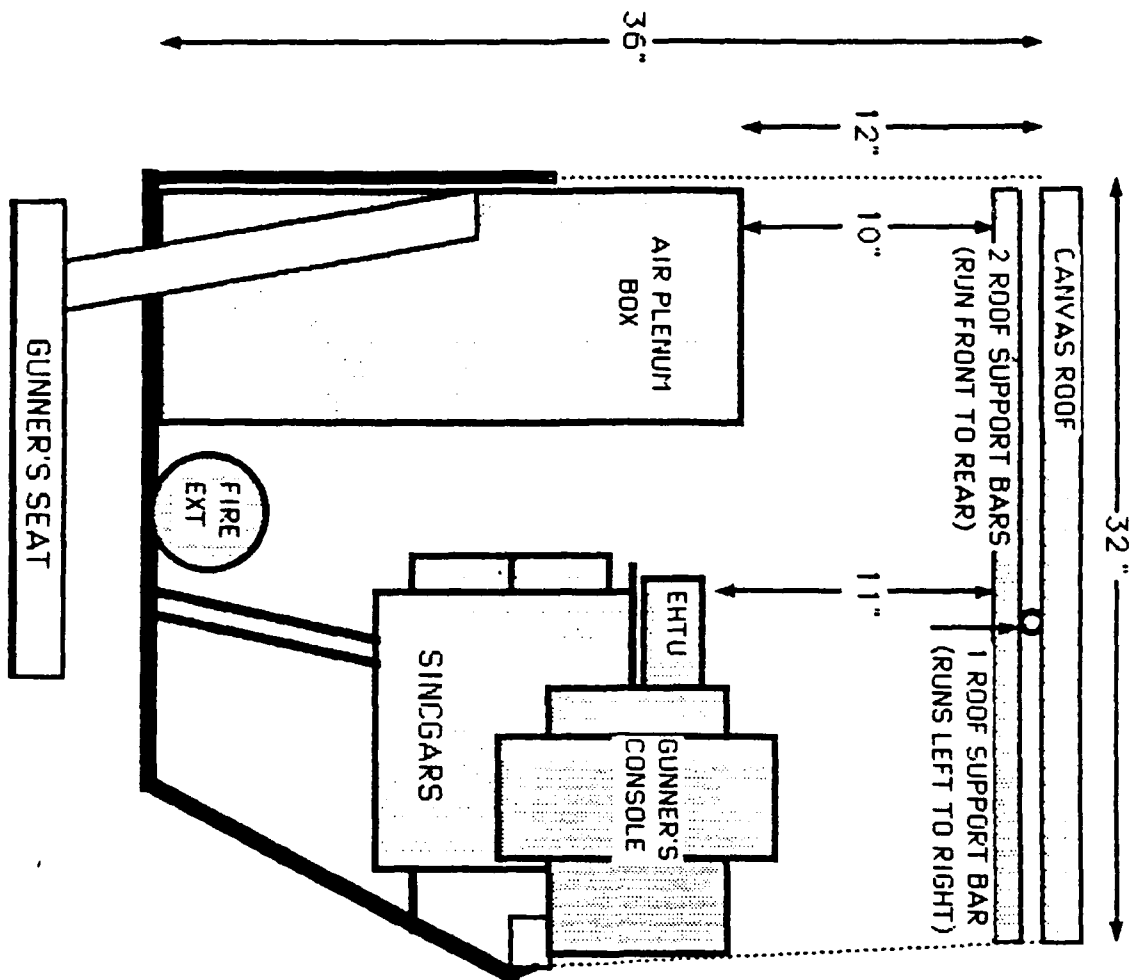
GUNNERS CONSOLE DESIGN CONCEPT (DIMENSIONAL)



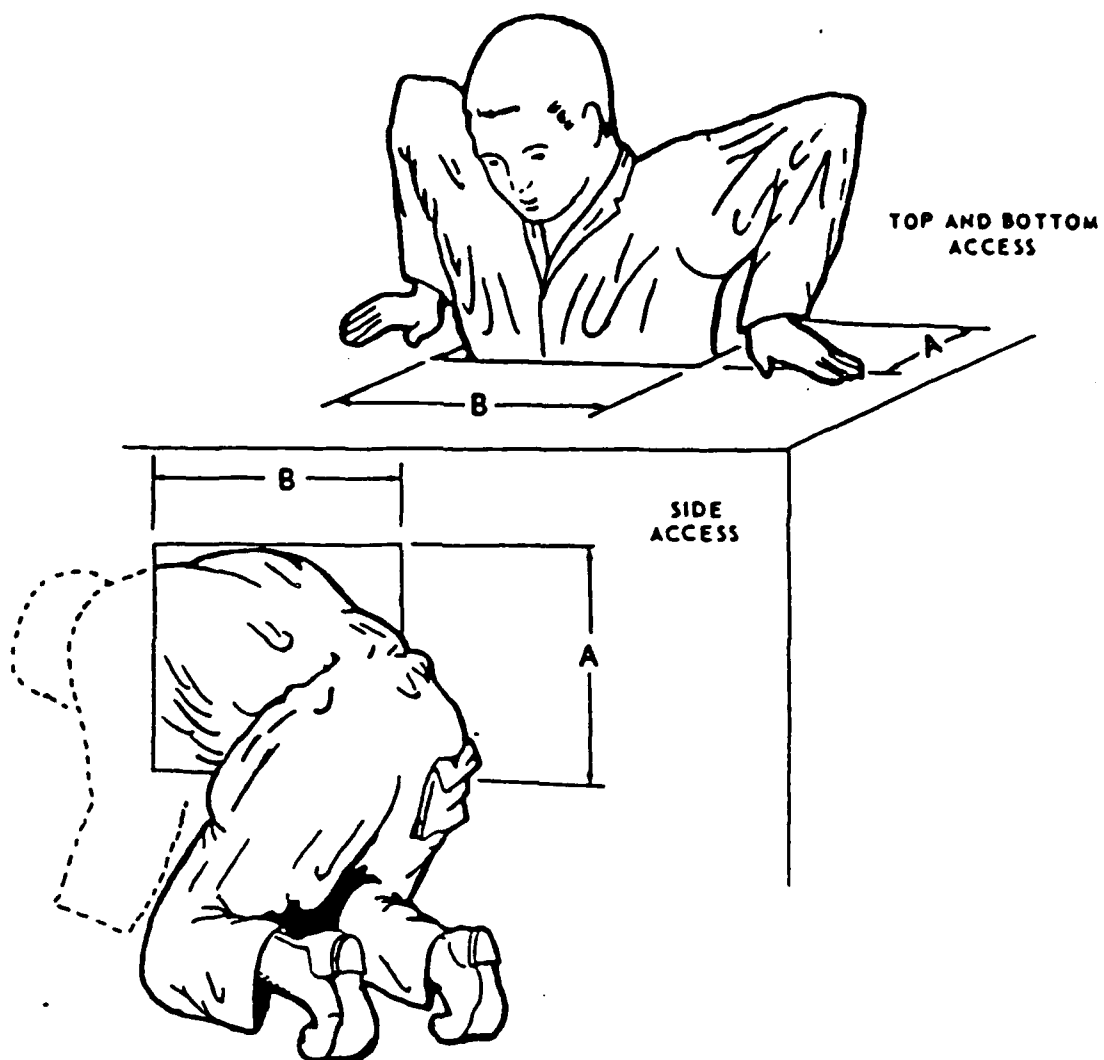
10/23/2000

encl 1

NLOS CREW COMPARTMENT WITH MOCK-UPS (GUNNER'S SIDE VIEW)



enc/ 2



DIMENSIONS	A. DEPTH		B. WIDTH	
CLOTHING	LIGHT	BULKY	LIGHT	BULKY
TOP AND BOTTOM ACCESS	330 mm (13 in.)	410 mm (16 in.)	580 mm (23 in.)	690 mm (27 in.)
SIDE ACCESS	660 mm (26 in.)	740 mm (29 in.)	760 mm (30 in.)	860 mm (34 in.)

NOTE: DIMENSIONS SHOWN BASED ON MALE DATA.

FIGURE 37. WHOLE BODY ACCESS OPENING

APPENDIX C

NLOS EMBEDDED TRAINER EVALUATION

DEPARTMENT OF THE ARMY
U.S. Army Research Institute for the Behavioral and Social Sciences
Fort Bliss Field Unit, P.O. Box 6057
Fort Bliss, Texas 79906-0057

PERI-SBC (70-n)

22 February 1991

MEMORANDUM THROUGH DIR, ARI FAAD MANPRINT TASK FORCE (ATTN: MAJ LEVITT)

TO: TRADOC SYSTEM MANAGER - FAAD, ATSA-TSM-F, (ATTN: MAJ FEDAKO)

SUBJECT: NLOS EMBEDDED TRAINER MANPRINT EVALUATION

1. PURPOSE: Evaluate NLOS Initial Operational Evaluation (IOE) system Embedded Trainer (ET) system within the NLOS Extended User Employment (EUE) program to identify soldier tasks, task performance requirements, and performance trends. Compare the NLOS ET characteristics to ARI developed Embedded Training Test and Evaluation guidelines. Develop a preliminary NLOS IOE ET engagement task performance data base in order to further explore soldier task performance trends and engagement outcomes under various conditions.

2. RATIONALE: The NLOS IOE fire unit ET system task and human performance evaluation is part of the EUE MANPRINT program effort to identify soldier tasks, and task performance requirements early in NLOS system development. The NLOS System MANPRINT Management Plan (SMMP) specifies objectives and concerns related to task skill and aptitude requirements, as well as specific issues regarding the NLOS Embedded Training system. Current MANPRINT NLOS IOE Embedded Training efforts are directed at identifying concerns, gathering data, and making evaluations to answer the issues outlined in the SMMP, as well as supporting other information requirements as they arise.

3. NLOS ET BACKGROUND: ET has been described as that training which results from features incorporated into the end item equipment to provide training and practice using that end item equipment. With the NLOS IOE system the features are completely embedded within the system configuration by a software application. ET features must include stimuli necessary to support training, and should provide (1) a performance assessment capability, (2) appropriate feedback, and (3) record keeping. Army policy dictates that ET be the first alternative reviewed for providing training in these categories: individual operator or maintainer, crew, functional area, and force level.

For the NLOS IOE ET system the gunner first selects the "Simulation Launch" option from the Gunner's Console main menu, and then has the opportunity to select simulated NLOS target engagement scenarios from either a "Fixed" or "Variable" scenario menu. After following the launch control procedure and enabling the fire switch, the simulated launch begins. The Digital Map Generator (DMG) provides simulated terrain through the implementation of a database, and updates from the missile processor to the DMG via the Console Processor provides the illusion of "flying over" the terrain. The gunner can move the joystick, changing the seeker view or manually guiding the missile, just as in a real flight situation, and the DMG terrain simulation will respond accordingly.

When using the "Fixed" scenarios, the launch point is automatically set (which may be different from the gunner's actual vehicle position) and a pre-determined target area is displayed. This is the target the gunner must hook if he wishes to engage the target described in the scenario menu. If the target area represents a moving air target, then this target area is an intercept point designed to take the missile into the path of the target - it is not the initial position of the target.

The "Variable" scenarios are more like real tactical situations. The gunner refers to detailed Scenario Maps before selecting a specific scenario. The Variable scenarios, unlike the Fixed scenarios, will allow the gunner to use any pre-planned target areas or routes. By moving the launch site, the gunner can practice engaging a target from different approaches. Also, the system will randomly select half of the targets available for a particular scenario for actual presentation during the engagement, which increases variability. For both Fixed and Variable scenarios, the targets do not start moving until the gunner flips the "FIRE ENABLE" switch.

4. METHOD:

a. Collect soldier Embedded Trainer task performance data on NLOS IOE ET using video tape, analyst observations, and after action debriefs.

- Conduct a pilot data collection effort to identify key task performance variables and develop data collection tools.

- Collect data on each of the 26 Fixed Scenarios.

- Collect data on each of the 16 Variable Scenarios.

b. Review video tapes to identify start and stop times for tasks, range to target area, and error information for a sample of scenario trials.

c. Develop a preliminary MicroSAINT soldier performance computer model incorporating NLOS IOE ET tasks, and task performance time data in order to further

explore soldier task networks. For example, a task such as target identification could be given various time and error performance values and entered into the model to explore what impact it might have on the time and range to target at which other tasks must be performed.

d. Army Research Institute for the Behavioral and Social Sciences (ARI) and the Project Manager for Training Devices (PM TRADE) has produced a series of ten related documents sharing the general title of Implementing Embedded Training (ET). This series of documents includes guidelines and procedures that support the effective consideration, definition, development, and integration of embedded training (ET) capabilities for existing and developmental systems. Volume 7 of this series, Embedded Training Test and Evaluation, identifies eleven Required Technical Characteristics for Embedded Training systems. The NLOS EUE MANPRINT support effort has addressed these eleven characteristics in an effort to provide a systematic and comprehensive assessment of the system.

5. RESULTS:

a. Soldier NLOS ET task performance data collection:

- The pilot data collection effort was conducted 12 June 1990 at Ft. Bliss. Two experienced NLOS gunners described their actions as they conducted several ET engagements. A video camera positioned over the right shoulder of the gunner recorded both audio and video data for the engagements. In the video, the gunners describe what they are doing, and why, as they walk the viewer through the ET system to include all button pushes, scenario selection from the menu, and engagement events performance. As an example of the supporting information available for each scenario, Appendix 1 provides the target movement data and engagement map for scenario #16 (attack against a four helicopter squadron).

- Fixed scenario task performance was gathered at Ft. Bliss 27-28 June, 1990. Each of the 26 Fixed scenarios were video taped on VHS format as four NLOS gunners carried out engagements. Each gunner conducted either the scenarios 1-13, or 14-26, and an additional set of four scenarios (#8, #11, #16, #18), yielding a total of 68 ET scenario trials in the video tape data base. A sample of 12 of the 68 trials was reduced to obtain task time and range to target area data. Information from the remaining trials will be reduced as necessary to meet any additional requests for scenario specific information.

- Variable scenario data collection was conducted 20-22 September, 1990. Problems were encountered as it was not clear how to effectively exercise the 16 Variable scenarios. A single run through of each scenario was recorded. Many of the key features and capabilities of the Variable scenario ET software were not exercised or explored. Proper use of the Variable scenarios required that the gunner have the full size paper maps displaying target positions which were provided for each of the 16

scenarios. Gunners would use the maps to decide on where to position the fire unit, and the target coordinates to fire on. Gunners were not confident about their ability to carry out the Variable scenarios, and were discouraged when they were unable to find targets during preliminary engagement trials.

b. Videotapes were reviewed to identify soldier performance tasks associated with the IOE Embedded Training system. A preliminary task list reflecting task performance from the pilot study videotape was created (see Appendix 2). A streamlined task list focusing on the engagement was used to record task time, and range to target area data from the videotaped scenario performance data (see Appendix 3). Task performance times and ranges for scenarios #6, #11, #16, and #18 were compiled from the videotaped data for preliminary evaluation of gunner task performance trends (Tables 1-4). ET data reduced from these four scenarios was used to illustrate the time-stressed human task performance demands of the NLOS system (Figure 1), which would also include a requirement for target identification. The breakdown of performance data provides a first empirical look at how gunner performance differs both within and between engagement scenarios. This is a first step toward identifying measurable performance standards or criteria for each scenario. The identification of key tasks and performance standards is a prerequisite for the development of automated performance scoring schemes, and feedback displays for ET or other training systems. Sample ET performance feedback displays will be presented later in this paper.

c. A preliminary MicroSAINT soldier performance computer model was developed by ARI Ft. Hood and ARI Ft. Bliss incorporating NLOS IOE ET tasks, and task performance times. MicroSAINT is a system that lets users develop, execute, and analyze the results of network simulation models. In the case of NLOS ET, MicroSAINT is used to explore soldier performance trends and engagement outcomes under various conditions, such as changes in task performance time or reliability. Estimates of gunner task performance from a quick review of the trials on Fixed Scenarios #6, #11, #16, and #18 were entered into the preliminary model. The model randomizes task performance across trials and yields new combinations of existing trial data. An example of the NLOS ET engagement task timeline output provided by the MicroSAINT model is presented as Figure 2.

d. ARI Research Product 89-02 identifies eleven Required Technical Characteristics for embedded training systems. The NLOS IOE ET system was evaluated in terms of these characteristics in an effort to provide a systematic and comprehensive assessment of the system. The review of the ET system against the eleven characteristics is summarized in Figure 3. The detailed review of the IOE NLOS system's Embedded Trainer with regard to each of the eleven Required Technical Characteristics follows:

TABLE 1

ENGAGEMENT TASK PERFORMANCE CUMULATIVE TIME, AND RANGE TO TARGET AREA
SCENARIO #6 (Two Helicopters Crossing)

ENGAGEMENT TIME(SECONDS)/RANGE TO TARGET AREA (METERS)

<u>TASK</u>	<u>TRIAL 1</u>	<u>TRIAL 2</u>	<u>TRIAL 3</u>
1. "Enable Fire"	0/5150	0/5150	0/5150
2. "Auto Search" Start	8/4500	8/4500	8/4500
3. Zoom Seeker Manually (1st)	36/1480	10/4200	18/3458
4. Slew Seeker Manually (1st)	11/4143	12/3900	22/3086
5. Target In Field Of View	7/4560	12/3900	15/3880
6. Start Seeker Slew To Target (Target Detected)	11/4143	13/3800	16/3500
7. End Seeker Slew	30/2229	18/3310	34/1640
8. First "Lock-On" Try	30/2121	40/1200	36/1481
9. First "Break-Lock"	30/2067	None	48/*
10. Second "Lock-On" Try	33/1906	—	1:49/*
11. Second "Break-Lock"	None	—	None
12. Target Identified	Don't Know	Don't Know	Don't Know
13. Missile Impacts Target	48/Hit	48/Hit	2:02/Hit
14. Trial 1 Comments: None.			
15. Trial 2 Comments: None.			

16. Trial 3 Comments: Missile flew by target at 48 seconds, gunner made a U-turn and re-engaged target successfully at 2:02.

*Missile reached original target area and distance to target indicator stopped at 499.

TABLE 2

ENGAGEMENT TASK PERFORMANCE CUMULATIVE TIME, AND RANGE TO TARGET AREA
SCENARIO #11 (Short Flight To Tank On Road)

ENGAGEMENT TIME(SECONDS)/RANGE TO TARGET AREA (METERS)

<u>TASK</u>	<u>TRIAL 1</u>	<u>TRIAL 2</u>	<u>TRIAL 3</u>
1. "Enable Fire"	0/3842	0/3842	0/3842
2. "Auto Search" Start	Immediate	Immediate	Immediate
3. Zoom Seeker Manually (1st)	16/2320	7/3300	18/2300
4. Slew Seeker Manually (1st)	10/3000	7/3300	11/3000
5. Target In Field Of View	11/2845	5/3570	Never
6. Start Seeker Slew To Target (Target Detected)	14/2583	8/3240	---
7. End Seeker Slew	30/879	23/1619	---
8. First "Lock-On" Try	31/664	25/1244	---
9. First "Break-Lock"	None	29/977	---
10. Second "Lock-On" Try	---	None	---
11. Second "Break-Lock"	---	---	---
12. Target Identified	Don't Know	Don't Know	Don't Know
13. Missile Reaches Target Area	39/Hit	33/Miss	34/Miss

14. Trial 1 Comments: Good detection, lock-on, and fly to impact.

15. Trial 2 Comments: Gunner pinned seeker looking at target, but not guiding the missile to the target, over flew target, U-turn, crashed in turn at 46 seconds.

16. Trial 3 Comments: Gunner immediately pinned seeker left, never got a target in this left direction field of view, U-turn, crashed at 2:33.

TABLE 3

ENGAGEMENT TASK PERFORMANCE CUMULATIVE TIME, AND RANGE TO TARGET AREA -
SCENARIO #16 (Four Helicopter Squadron)

ENGAGEMENT TIME(SECONDS)/RANGE TO TARGET AREA (METERS)

<u>TASK</u>	<u>TRIAL 1</u>	<u>TRIAL 2</u>	<u>TRIAL 3</u>
1. "Enable Fire"	0/6357	0/6357	0/6357
2. "Auto Search" Start	20/4500	20/4500	20/4500
3. Zoom Seeker Manually (1st)	35/2942	17/4700	33/2973
4. Slew Seeker Manually (1st)	28/3610	18/4600	23/3821
5. Target In Field Of View	7/5778	6/5819	24/3768
6. Start Seeker Slew To Target (Target Detected)	31/3289	17/4700	32/3079
7. End Seeker Slew	48/1332	35/2800	48/1400
8. First "Lock-On" Try	48/1332	38/2512	49/1359
9. First "Break-Lock"	49/1280	39/2457	49/1359
10. Second "Lock-On" Try	None	57/1564	None
11. Second "Break-Lock"	—	58/1525	—
12. Target Identified	Don't Know	Don't Know	Don't Know
13. Missile Reaches Target Area	1:04/Hit	1:06/Miss	59/Miss

14. Trial 1 Comments: Gunner used manual guidance to impact after 1st break-lock occurred.

15. Trial 2 Comments: Missed, gunner pegged seeker slew looking to the right, this should be the reason why he flew to the left of the target, didn't point the missile to where he was looking.

16. Trial 3 Comments: Bro' > lock at 49 seconds, flew by target at 59 seconds, crashed while making a manual turn at 1:18.

TABLE 4

ENGAGEMENT TASK PERFORMANCE CUMULATIVE TIME, AND RANGE TO TARGET AREA -
SCENARIO #18 (Two Helicopters Turning Toward Fire Unit)

ENGAGEMENT TIME (SECONDS) / RANGE TO TARGET AREA (METERS)

<u>TASK</u>	<u>TRIAL 1</u>	<u>TRIAL 2</u>	<u>TRIAL 3</u>
1. "Enable Fire"	0/8302	0/8302	0/8302
2. "Auto Search" Start	38/4487	38/4487	38/4487
3. Zoom Seeker Manually (1st)	26/5800	49/3327	55/2978
4. Slew Seeker Manually (1st)	15/7173	44/3700	14/7171
5. Target In Field Of View	28/7000	56/2429	48/3376
6. Start Seeker Slew To Target (Target Detected)	20/6500	56/2429	53/2700
7. End Seeker Slew	47/3548	56/2429	1:13/*
8. First "Lock-On" Try	48/3496	1:54/*	1:51/*
9. First "Break-Lock"	59/2214	1:55/*	None
10. Second "Lock-On" Try	1:09/1212	2:02/*	---
11. Second "Break-Lock"	1:12/840	None	---
12. Target Identified	Don't Know	Don't Know	Don't Know
13. Missile Reaches Target Area	2:21/Miss	2:08/Hit	2:10/Miss

14. Trial 1 Comments: Broke lock about 5 times, last was too late for any other actions. Tried to lock-on seeker far out, or in wide field of view.

15. Trial 2 Comments: None

16. Trial 3 Comments: Good early detect, waited to put tracker box on target, good lock until missile flew by target at 2:10.

*Missile reached original target area and distance to target indicator stopped at 499.

FIGURE 1

NLOS EMBEDDED TRAINER ENDGAME PERFORMANCE

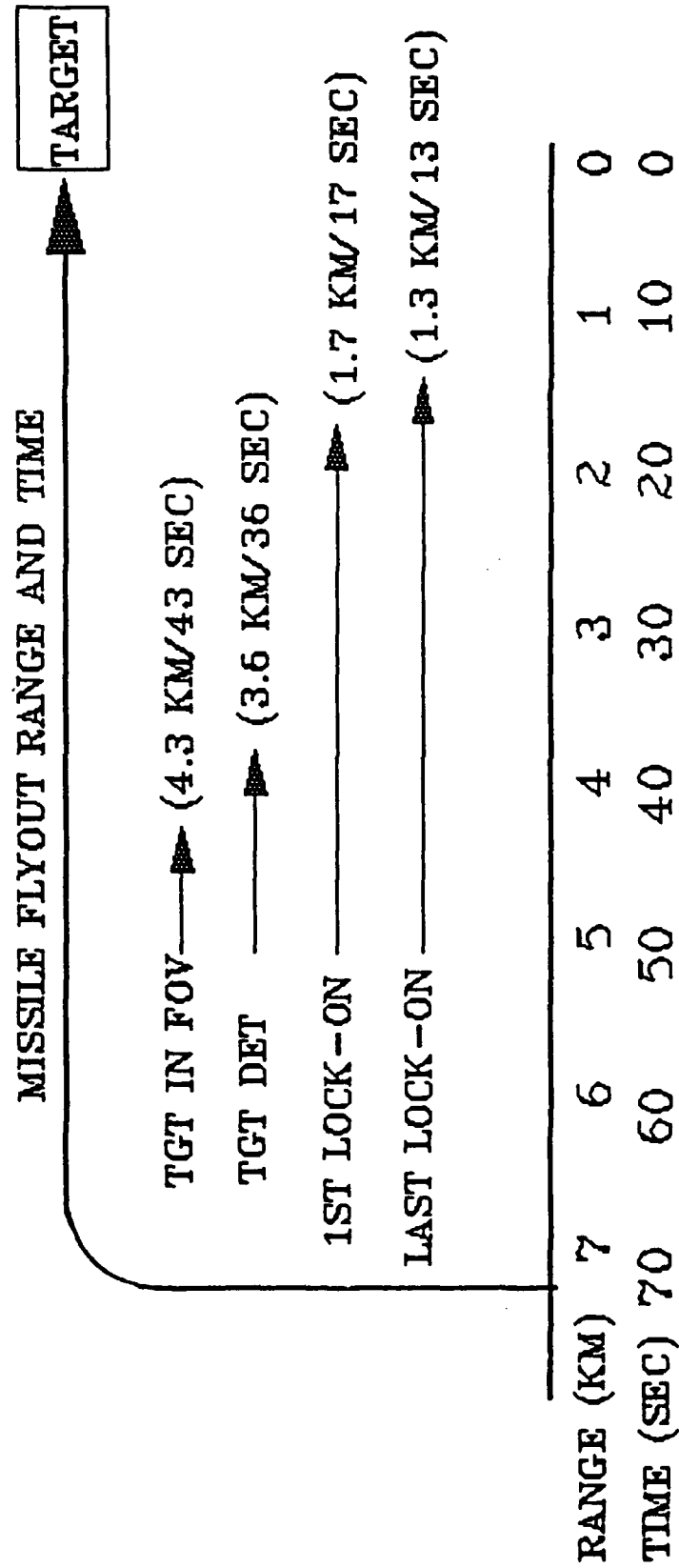


FIGURE 2

MICROSAINT TASK PERFORMANCE TIMELINE

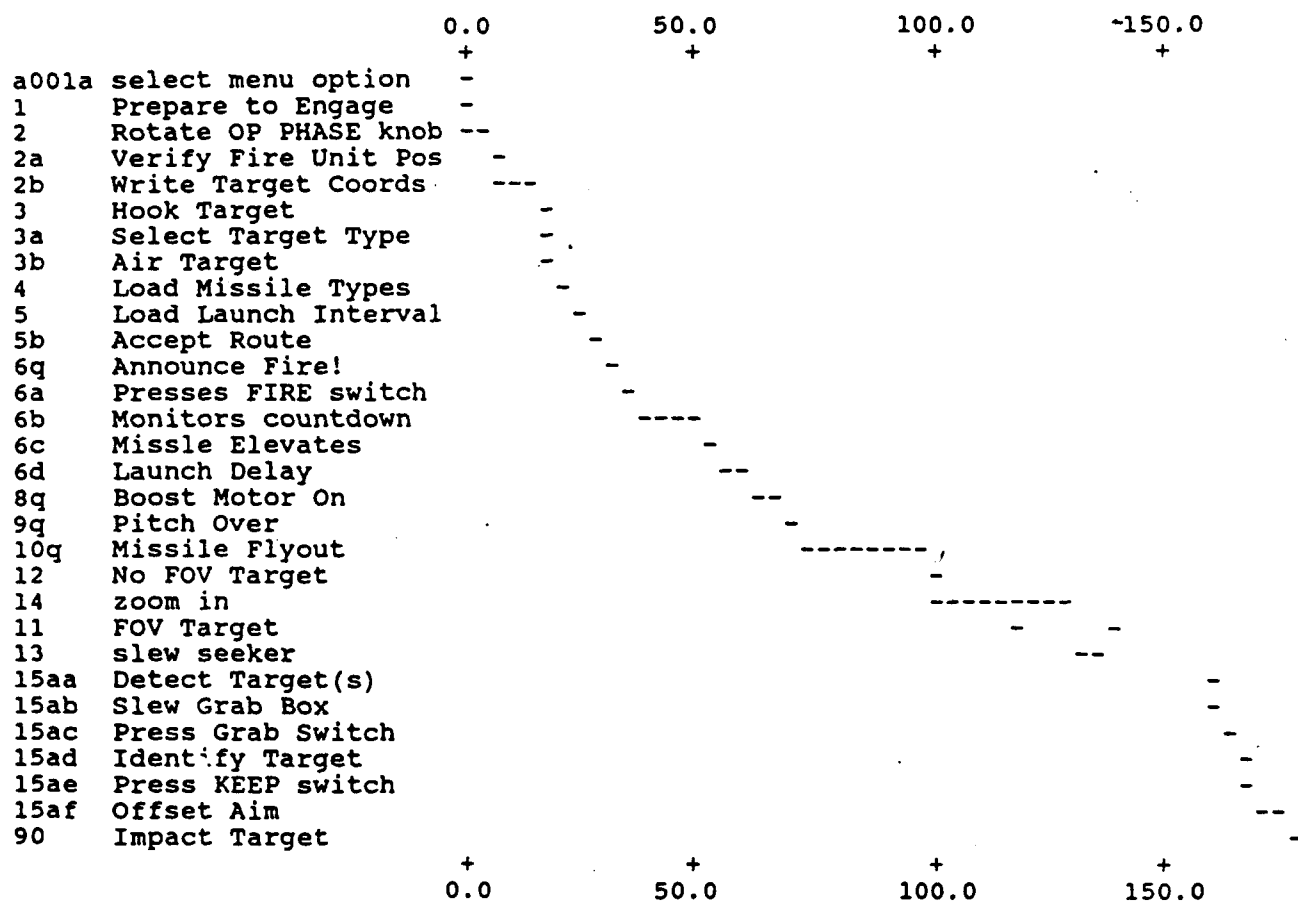


FIGURE 3

NLOS EMBEDDED TRAINER CHARACTERISTICS EVALUATION

1. Time required to transition into and out of ET.
 - Gunners can quickly transition into and out of ET.
2. ET logistics burden.
 - No ET logistics concerns were identified.
3. Levels and types of training delivered by ET.
 - Concern: Content is limited to target engagement, could be broadened in scope to optimize total POI ET sustainment training potential.
4. Number of training scenarios and variety prevent memorization.
 - "Variable" scenarios provide flexibility needed to prevent memorization.
5. Training content or topics.
 - Concern: ET automatically provides target intercept point, transparent to the gunner. Artificial feature replaces key mental task training.
6. Dependence on instructors or training managers when using ET.
 - Gunners exercise ET without assistance, replay with on-board videotape.
7. Required level of fidelity of simulations.
 - Constraints: Single missile, daylight only, no target identification, no time pressure to launch, automatic target intercept calculation.
8. Performance evaluation and assessment capability.
 - Concern: No performance summary or record except videotape. No diagnostic comparison of task performance to standards.
9. Performance data security.
 - The only potential data source is the optional videotape record.
10. Feedback in support of effective learning.
 - Concern: No performance feedback against an "expert" standard.
11. ET adaptability, respond to soldier performance and strengthen weak areas.
 - Concern: Need to evaluate performance and provide a software message to direct gunner to appropriate ET scenario or lesson in a training matrix.

Characteristic 1. Allowable times to transition into and out of ET.

Overview: Gunners can quickly transition into and out of the ET mode of operation.

Observations:

- Time required to transition into ET scenario menu after system initialization was approximately 1 minute and 30 seconds for the first scenario. Missile BIT was not required between ET scenarios so that the time between the end of one scenario and the arrival at the menu for the next scenario was approximately 1 minute. Time required from the selection of a scenario in the menu, until the gunner hits the "Fire Enable" switch was approximately 1 minute and 20 seconds. All times were taken from the pilot data collection effort.

- Time required to transition out of ET is minimal. At any time the NLOS gunner can move the Gunner's Console "Training/Firing" switch into the "Firing" position and return immediately to the main menu.

Characteristic 2. Allowable logistics burden for ET and any appended component requirement.

Overview: The NLOS ET system logistics support requirement does not appear to be different from that of the fire unit.

Observations:

- NLOS ET components are essentially software. The NLOS IOE fire unit was able to hook-up to a fixed power supply to eliminate the need for running the vehicle motor.

Characteristic 3. Levels or types of training to be delivered by Embedded Training (e.g., acquisition, sustainment, expert).

Overview: Training content selection should begin with a review of the training POI. Try to expand training content to maximize the potential of ET as an interactive computer based training system.

Observations:

- The NLOS IOE ET system provided target engagement training at the skills sustainment level. The ET system provided switchology familiarization, and practice on NLOS-specific hand-eye coordination tasks. Target identification was not trained due to limitations in the fidelity of the screen imagery.

- The training content of the NLOS IOE ET system may be too limited, as it trains engagement tasks. Future NLOS ET development should work toward greater utilization of the Computer Assisted Training potential of the on-board interactive video computer technology. Much of the NLOS training program that is presented in the classroom or in textbook form (to include the line drawing and still picture portions of Aircraft Identification training) could be sustained with ET. A first step would be to review the NLOS training Program Of Instruction (POI) identifying those tasks which should be considered for ET sustainment. The ET training focus should be on critical tasks, tasks identified as needing frequent sustainment training, and tasks which are not commonly practiced, such as degraded modes of operation, and maintenance tasks.

Characteristic 4. Number of scenarios and the required variability of training (e.g., location-specific scenarios, expert-level scenarios). Also, sufficient variety to prevent memorization and boredom.

Overview: The NLOS IOE ET system provides 26 "Fixed" and 16 "Variable" target engagement scenarios. Some of the NLOS gunners appeared to have memorized key features of the Fixed scenarios, such as where to look for targets, and how targets would move. In contrast, the Variable scenario option appears to provide for sufficient variety to prevent memorization and boredom, however problems encountered in collecting data on Variable scenarios limits this conclusion.

Observations:

- The ET database contains sixteen different simulated battlefield scenarios. Each scenario contains one or more targets to include helicopters, tanks, trucks, jeeps, ammunition, or buildings.

- For Fixed scenarios the sixteen basic scenarios are rearranged to present twenty-six canned scenarios where fire unit location and target movement are predetermined. The same targets will always appear in a given scenario, and for moving targets an intercept area is provided to the gunner. It was observed that some gunners had memorized some aspects of the Fixed scenarios so that they could search in a limited area where they knew the targets would be.

- For Variable scenarios the gunner is presented with the sixteen basic scenarios, but has the option of selecting alternative sites to position the fire unit at and engage targets, thus allowing the gunner to build a number of different engagements around the basic set of sixteen target scenarios. Variable scenarios present a random sub-set of targets from a larger pool for each scenario which should add to variety and lessen the chance of memorization.

- One means to increase variability and prevent memorization of the limited number of scenarios would be to simply call up the same scenarios, but under an extended menu numbering scheme. While gunners might be able to remember basically what happens in

16 or 26 scenarios, they would be less likely to do this if each scenario were repeated in random order four times so that perhaps 100 scenario titles were presented in the menu, each with a slightly different description or set of target data.

Characteristic 5. Training content or topics (e.g., failure modes, multiple targets, maintenance).

Overview: A discussion of the adequacy of NLOS ET content or topics should begin with the identification of the total NLOS training program needs, perhaps best reflected in the training POI. The NLOS IOE ET system training content was limited to target engagement tasks. ET content should be expanded to optimize its potential for sustainment of other training content, perhaps with a greater emphasis on sustainment of classroom and textbook material presented in the POI.

Observations:

- One major concern is that the ET system artificially performed a task that the gunners need to be trained to perform. The system automatically calculates an intercept point for moving targets, transparent to the gunner, and presents this to the gunner instead of the original target coordinates, so that the missile will automatically fly into the path of the target. In real life the target intercept calculation task will probably be allocated to the gunner, not the machine. The current ET system may be doing a disservice to the gunner by masking-over this important training requirement.

- A number of training elements were not included in the ET system:

- multi-round launch where the gunner must assume control of a second missile already late in its flight.

- recognition and identification tasks were not exercised, which makes extra time available for the gunner to perform other time stressed end game tasks.

- the target movement related time stress for planning is not accurately represented, as targets don't start moving until the "Fire Enable" switch is activated. Target engagement task performance demands would be better represented if target movement began when the scenario was selected from the training menu.

- no system failure modes.

- no Imaging Infrared (IIR) seeker scenarios.

- no weather or climate condition variation.

Characteristic 6. Allowable extent of dependence on instructors or training managers during Embedded Training sessions.

Overview: ET should provide a stand alone training capability for gunners. To the extent that an NLOS gunner can not infer what his mistakes are, and what corrective actions to take, instructors and training managers will be needed to support effective learning.

Observations:

- Gunners can play back their performance for assessment using the on-board video recorder.

- During the data collection recording of the Variable scenarios it was found that the procedures for running the scenarios were not well understood and that an "operating instructions" capability was not built into the system. Consider adding a "Help" option on the menu to bring up a page of instructions on how to set up and proceed through the Variable scenarios.

- Currently no automated capability for student task performance scoring. Training managers should identify key tasks and create a performance checklist that could be built into the ET software for each scenario to help assess individual gunner proficiency, and platoon training needs.

- There is no guidance provided within the ET system for scenario sequencing. A recommended sequence strategy to support or free-up trainers should be developed. ET should be able to automatically make a "next scenario" recommendation (or requirement) based on a gunner's success or failure in a given scenario, to lead the gunner through a series of progressively more difficult training exercises.

Characteristic 7. Required level of fidelity of simulations.

Key soldier tasks should be simulated in as much detail as possible (e.g., visual scene fidelity, realistic communications, and task performance time constraints).

Overview: The NLOS visual simulation requirements have been specified in terms of required target image size for a given range, and resolution lines on target, to allow for realistic target detection training. Key NLOS engagement training requirements include communications (call for fire), mission planning (moving target intercept calculation), missile fly-out and search phase, and the target engagement endgame. The NLOS IOE ET system shows some important shortcomings in terms of communications and mission planning that could be corrected. The target information presented in the scenario message does not reflect the type of command and control information that would normally be provided to the gunner. The time pressure pushing task performance in a real engagement is missing because target movement does not start until the missile is launched (this could be changed to the time the scenario is selected from the menu).

The important task of calculating a missile intercept point against a moving target is not trained in the Fixed Mission scenarios, as this is automatically provided to the gunner. It remains to be determined whether the target detection range performance displayed by gunners (targets detected in the seeker field of view (FOV) as far out as 7km in scenario #18) is an accurate reflection of a real world capability.

Observations:

- The scenario menu target information does not match what would be expected in an air defense call for fire. This should be an easy situation to correct. As example, for Fixed scenario #16 the ET menu tells the gunner "A 4 HELLO SQUADRON". Based on the hard copy supporting information for this scenario the gunner could be told "Hinds, four, position coordinate is 391372, moving on azimuth 280 degrees at 70 meters a second".

- The ET engagements against moving air targets significantly underestimate some key mental task requirements. It is important to recognize that the NLOS ET system automatically calculates a target intercept point designed to take the missile into the path of the target - it does not present the initial position of a moving air target. Likewise, the ET system does not start target movement until the moment when "Fire Enable" occurs, so that the target does not move, and the intercept point does not change, while the gunner prepares to fire. In a real engagement the gunner will have to be able to calculate the moving target intercept point, and will have to be able to factor in any delays that occur after the original target location is identified, to include the time required to make the intercept calculation. ET target areas which represent stationary ground targets are the approximate initial position (and terminal position) of the target or a group of targets.

- Target area entry and update was not required in the 26 Fixed scenarios.

- Launch tasks appear to be an accurate representation of real tasks.

- Missile fly-out, and auto search to bring a target into the seeker FOV appears to provide an accurate representation of mechanical tasks.

- Is the ET system target image size an accurate representation of the image size a gunner would see on the screen in a real engagement? Look at detection range data, comparing ET performance to Captive Flight Testing and Live Fire detection range data to establish the validity of performance trends obtained from the ET system.

- Given detection, target identification is a significant and difficult task that should require some time in the final moments of the engagement. Target ID was not played in NLOS IOE ET trials that were videotaped, as all detected targets were engaged. The target identification task and time requirement should be modeled for further evaluation.

- The NLOS ET system makes no provision for multiple missile launch and the resulting time stressed end game tasks.
- Missiles frequently appeared to veer off both ground and air targets at the last second prior to impact.
- Seeker break-lock occurred frequently during Embedded Training scenarios. Is the ET seeker performance an accurate reflection of real seeker performance?
- IIR seeker engagements are not simulated with the ET system.
- The NLOS IOE ET system allowed gunners to fly missiles in a 180 degree turn and come back at a target that has been missed. This missile capability has not been demonstrated. Should gunners train for a "U-Turn" capability with the ET system?

Characteristic 8. Performance evaluation and assessment capability.

Overview: ET should provide for (1) a performance assessment capability, (2) appropriate feedback, and (3) record keeping. The NLOS ET system does not provide these features as an automated function, and this could serve to limit the training effectiveness of the system. It should be possible to have these three functions automated into ET. Assessment and feedback must be built into the system, so the crew can train itself, which is the purpose of ET.

Observations:

- The NLOS IOE ET system allowed gunners to go through the process of a simulated engagement, and to replay a video tape of the trial.
- The NLOS IOE ET system did not record or present summary task performance for each scenario played, and gunner performance was not referenced against any performance standard.
- There was no indication of whether the NLOS gunner had engaged a friend or a foe (fratricide). This information might easily be presented as a simple message to the gunner at the conclusion of scenario play, "Target Is AH-64, Do Not Engage".
- The NLOS IOE ET system displayed a great deal of task performance information during scenario play which could be valuable for performance assessment and feedback if it were captured and summarized. This task performance information included a continuous readout of missile range to target area, which also allowed for an estimate of available task performance time. Switch flip actions, seeker zoom and gimbals angle, seeker lock and break-lock performance, and missile impact time might also be recorded as data points to assess whether gunners perform tasks in the order and time prescribed by training, or whether they are making errors which require correction.

Characteristic 9. Performance data security.

Observations:

- Currently the only source of performance data would be the on-board recorder.

Characteristic 10. Feedback in support of effective learning.

Overview: Typically, with regard to human task performance "You get what you measure". If ET seeks to shape gunner behavior toward a standard of task performance, then ET must feed back performance information on the specific subset of tasks in question. The current ET system can only provide a replay of the scenario, no evaluation, assessment, summary of performance, or comparison to any "expert" or "right way" performance standard for the scenario. If switch flip actions, button pushes, or screen data can be captured for a summary screen presentation at the end of the scenario exercise NLOS ET feedback might be provided in several forms.

Observations:

- By simply working through scenarios the gunner's learning is dependent on his short term memory (gunner recall) of task actions and performance outcomes.

- By using the video replay feature the gunner can refresh his memory of actions and outcomes, but if he can't recognize what went wrong this review may not help him.

- A simple summary record of key switch flip type tasks and when they occur with regard to time and/or range to target area might be a significant improvement to support effective learning. An example of this type of feedback is presented as Figure 4.

- A more accurate representation of task performance demands might be made by identifying "windows" of time (or range to target) in which the gunner can perform actions without adversely impacting the engagement outcome. The "windows" approach has the advantage of moving away from the single right answer "Expert" solution, and also identifies that performing a task "too early" might be as bad as "too late". The "windows" would be identified by working with the gunners and supporting personnel to identify useful or needed feedback, and work to automate this capability as much as possible. As example, the following might be provided as performance feedback:

- (1) Broke auto search too early
- (2) Seeker zoom magnification too wide for lock-on attempt
- (3) Attempted seeker lock-on too far from target
- (4) Fratricide - killed a friendly target

An illustration of how this task performance information and action feedback might be presented to a gunner is provided as Figure 5.

FIGURE 4

GUNNER TASK PERFORMANCE DATA: RANGE TO TARGET AREA

<u>ENGAGEMENT TASKS</u>									
1	FIRE ENABLE	-							
2	AUTO SEARCH		_____						
3	SLEW SEEKER			_____	_____				
4	ZOOM SEEKER			_____	_____				
5	TARGET DESIGNATE				_____	_____			
6	TARGET REJECT					_____			
7	OFFSET AIMPOINT						_____		
8	90 DEGREE TURN								
9	MISSILE IMPACT								-
<hr/>									
		5	4	3	2	'	1		0
(RANGE TO TARGET AREA IN KILOMETERS)									

FIGURE 5

GUNNER TASK PERFORMANCE: COMPARISON TO "WINDOW" STANDARD

<u>ENGAGEMENT TASK</u>	<u>EXPERT STANDARD</u>	<u>STUDENT PERFORMANCE</u>
1. CUE TO LAUNCH TIME	20-30 SEC	20 SEC
2. BREAK AUTO-SEARCH (TARGET IN FOV)	4560-3500m	4143m
3. SEEKER LOCK-ON - RANGE - ZOOM	2000-1000m NARROW FOV	2121m WIDE FOV
4. TARGET IDENTIFICATION	TRUE FRIEND (DON'T LOCK-ON)	FALSE THREAT (LOCK-ON)
5. INTERCEPT	NO	YES
<p>STUDENT GRADE: FAIL (SEE FEEDBACK)</p> <ul style="list-style-type: none"> * DO NOT ATTEMPT SEEKER LOCK BEYOND 2000m * DO NOT ATTEMPT SEEKER LOCK IN WIDE FOV. * REVIEW AH-64 APACHE HELO IDENTIFICATION <p>TRAINING TASK: REPLAY SCENARIO #6</p>		

- Target intercept prediction accuracy. ET could be very valuable in target intercept prediction training. Replay target data, the intercept formula, and the correct intercept solution v.s. the student's predicted intercept target area input.

- Again, expand coverage of training content beyond the target engagement tasks to the broader training POI.

Characteristic 11. Adaptability, so that the system can respond to soldier performance and adapt the presented training materials to strengthen weak areas.

Overview: In order to respond to soldier performance there must be some assessment of this performance. It should be a straight forward task to build in a "go to" recommendation for the next scenario to try, given success or failure in the previous scenario trial.

Observations:

- Build a matrix of progressively more difficult scenarios which center around basic skills such as mission planning, target identification, flying a dog-leg course, and others. Such a training matrix is built into the M1 tank Unit Conduct Of Fire Trainer.

- The variable scenarios could be highly adaptable to respond to soldier training needs, as different scenarios can be produced by simply changing the initial vehicle position and target information provided to the gunner in the scenario menu.

6. DISCUSSION: Overall, the NLOS IOE ET system provided a fairly realistic engagement simulation which would be useful in sustaining procedural skills and hand-eye coordination tasks.

- Suggestions short list:

- Start with the NLOS POI and identify all training content that could be sustained through ET, not just the engagement.

- Identify some task performance standards, time or range to target referenced criteria for desired performance.

- As a minimum, add some basic switch flip task time and range to target performance feedback for the gunners at the conclusion of each scenario.

- Present the scenario menu information phrased as FAADS command and control messages.

- Make a provision for target movement to start when the scenario is first selected from the menu, so that the time sensitive pre-launch tasks are realistically trained.

- Train the target intercept calculation task.

7. CONCLUSION: The NLOS IOE ET system appeared to be a valuable tool in its present form for providing target engagement training at the skills sustainment level. The ET system provided switchology familiarization, and practice on NLOS-specific hand-eye coordination tasks. Target identification was not trained due to limitations in the fidelity of the screen imagery. The NLOS IOE ET system fails to provide performance feedback to the gunner which is a significant concern. A systematic review of gunner task performance trends can provide performance standards that might be built into the ET system for an enhanced training potential.

Encl
as


WILLIAM SANDERS
Research Psychologist

APPENDIX 1

ET TARGET MOVEMENT DATA AND ENGAGEMENT MAP

FIXED MISSION # 16

MENU DESCRIPTION: A 4-HELICOPTER SQUADRON

TARGET DEFINITION: 4 SOVIET HELICOPTERS (HIND)

NARRATIVE DESCRIPTION:

A 4-HELICOPTER SQUADRON - AS YOU ARE COMING OVER THE HILL ON YOUR LEFT, THE HELICOPTERS SHOULD BE VISIBLE IN THE DISTANCE. IF THEY ARE COMING FROM THE LEFT, THEY WILL CHANGE DIRECTION SLIGHTLY AND HEAD TOWARDS YOU. AS THEY COME NEARER, THEY WILL CONTINUE TO CHANGE DIRECTION (TURNING TO YOUR LEFT) AND WILL ALSO SPEED UP.

MISSION INFORMATION:

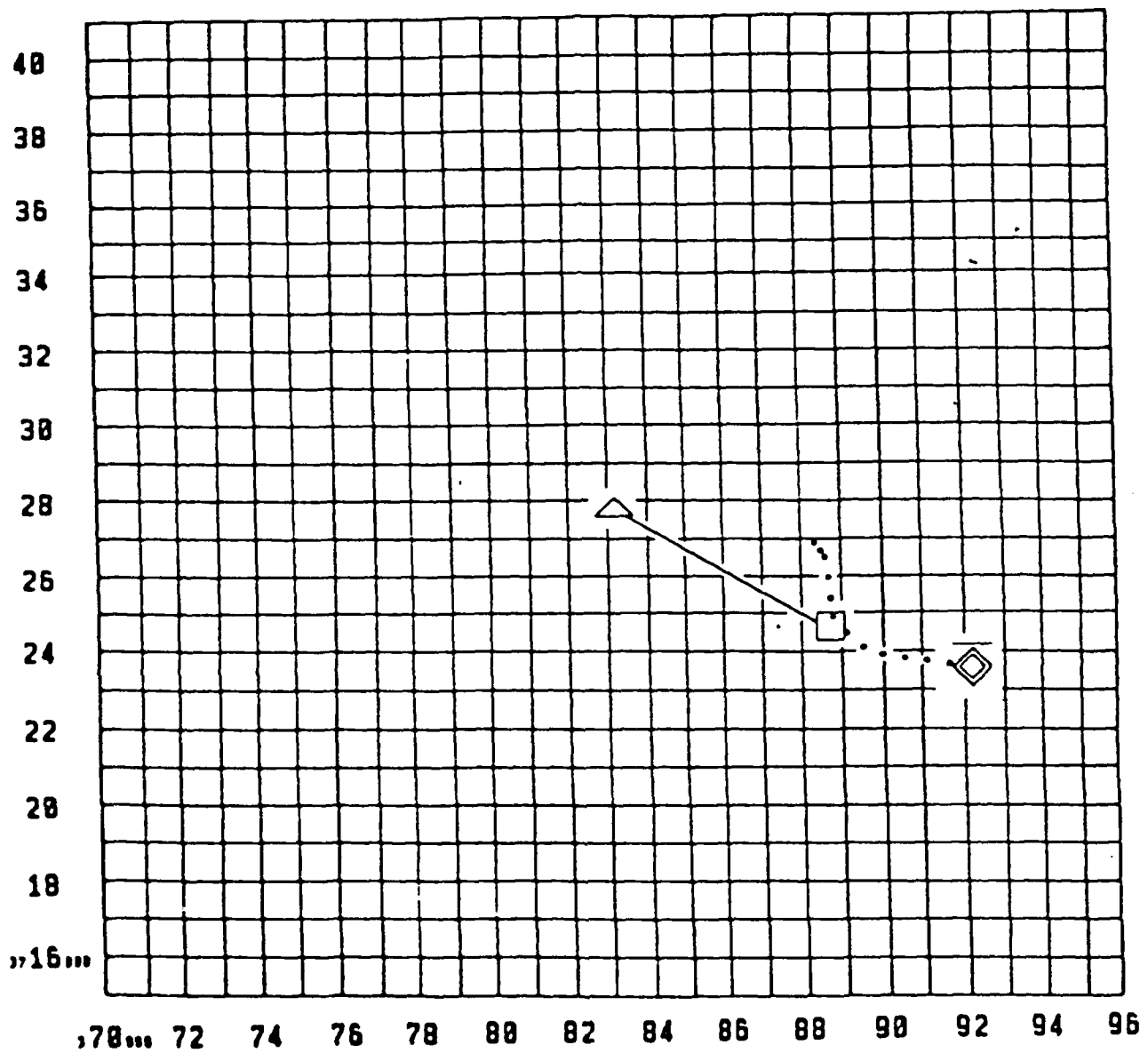
DMG SCEN#	VAR. TRACK#	MISSN. OFFSET	LS COORD:	INTERCEPT COORD:
9	903	8	383200E 3727800N	388750E 3724700N

TARGET TIME HISTORY INFORMATION
(NORMALIZED FOR 8 SECOND INTERVALS):

	X-DIS (M)	Y-DIS (M)	VEL (M/S)	HEADING (DEGREES)	POSITION (UTM METERS)
0 SECONDS:	0.0	0.0	0.0	0.0	392230E 3723570N
8 SECONDS:	-68.4	12.1	69.4	280.0	391683E 3723667N
16 SECONDS:	-68.4	12.1	69.4	280.0	391136E 3723763N
24 SECONDS:	-68.4	12.1	69.4	280.0	390589E 3723860N
32 SECONDS:	-68.4	12.1	69.4	280.0	390042E 3723956N
40 SECONDS:	-61.2	27.9	67.2	294.5	389552E 3724179N
48 SECONDS:	-53.9	43.7	69.4	309.0	389121E 3724529N
56 SECONDS:	-42.2	49.5	65.1	319.6	388783E 3724925N
64 SECONDS:	-7.0	66.9	67.3	354.0	388727E 3725461N
72 SECONDS:	-7.0	66.9	67.3	354.0	388670E 3725996N
80 SECONDS:	-7.0	66.9	67.3	354.0	388614E 3726532N
88 SECONDS:	-17.2	24.1	29.6	324.5	388476E 3726725N
96 SECONDS:	-17.2	24.1	29.6	324.5	388338E 3726918N

AVERAGE VELOCITY - 61.7

APPENDIX 1 (continued)



FIXED MISSION #16

APPENDIX 2

PILOT STUDY TARGET ENGAGEMENT TASK LIST

1. Select "Emplacement" from main menu.
2. Select "ENGINE ON".
3. Select "MISSILE BIT"
4. Select "MAIN MENU".
5. Select "SIM LAUNCH".
6. Select "FIXED" or "VARIABLE" ET engagement scenario.
7. Select scenario from menu (pull trigger to second detent).
8. Select "ENGINE ON".
9. Select number of missiles (always one).
10. Hook target (place icon on target box using joystick and pull through to second detent), or type in coordinates.
11. Computer asks if gunner wants to change any information (gunner selects "YES" or "NO").
12. Select "FIRE ENABLE".
(BOOST MOTOR ON, MISSILE PITCH OVER, MISSILE FLYOUT BEGINS)
13. Gunner performs missile azimuth correction if necessary. Gunner compares screen imagery to memory of map features to determine if missile is flying on correct azimuth. If azimuth correction is necessary, gunner moves the joystick to slew the missile seeker until the desired flight path is reached, then pulls the joystick trigger to second detent to input the new azimuth. Not required with the ET scenarios.
14. Select RIGHT TURN or LEFT TURN to change missile flight direction 90 degrees.
15. Rotate "BRIGHTNESS" adjustment knob as required.
16. Rotate "CONTRAST" adjustment knob as required.

APPENDIX 2 (continued)

("AUTO SEARCH" SEEKER ZOOM AND SLEWING BEGINS APPROXIMATELY 4.5KM FROM TARGET AREA)

17. Slew missile seeker manually by pressing the joystick thumb control in the desired direction.
18. Gunner can manually adjust the seeker zoom magnification by pressing the "ZOOM IN" or "ZOOM OUT" pushbuttons.
19. Gunner monitors "RANGE TO TARGET" distance screen readout to anticipate when targets might appear on the screen.
20. Gunner visually detects probable target, assumes manual seeker control if in the "AUTO SEARCH" mode.
21. Gunner visually investigates probable target, moves seeker crosshairs over target and zooms seeker in if necessary.
22. Gunner visually identifies the target as a threat or friend.
23. Gunner determines when missile is close enough to the target, and when target provides sufficient contrast against the background, and attempts a seeker lock-on.
24. Gunner attempts lock-on by slewing the seeker crosshairs onto the target and pressing the "TGT DES" pushbutton.
25. If gunner detects that the seeker has broken its contrast lock on the target he presses the "TGT REJ" pushbutton.
26. Gunner repeats the lock-on procedure, or manually guides the missile to impact by keeping the crosshairs on the target.
27. Given seeker lock-on, the gunner can further lock the missile onto a particular area of the target by placing the crosshairs on the target impact point and pressing the "OFFSET AIMPT" button.
28. Gunner visually determines missile impact on the target or miss.
27. Gunner can select two RIGHT or LEFT turns to make a 180 degree turn and attempt to relocate a missed target.
28. After missile impact, gunner flips the "FIRE ENABLE" switch down.
29. Select "ESCAPE", and then "SPARE 1" pushbuttons.
30. Select "RETRACT MISSILE" pushbutton.
31. Computer is now back in the system menu.

APPENDIX 3

NLOS ENGAGEMENT TASK TIME AND RANGE VIDEO REDUCTION SHEET

1. Start Engine message (push PDP button)
2. Select # missiles message (push PDP button)
3. Hook Target message (joystick, keyboard, or azimuth)
4. Change Target Info message (push button for yes or no)
5. If yes on 5 above, change target info (how?)
6. Push Enable Fire switch
7. Target range at zero seconds
8. Auto search starts
9. Manual over ride of auto search
10. Zoom seeker manually
11. Slew seeker manually
12. Target in FOV
13. Target detected, gunner starts seeker slew
14. Gunner ends seeker slew onto target
15. First lock attempt
16. First Tracker Coasting message

APPENDIX 3 (continued)

17. Second lock attempt

18. Second Tracker Coasting message

19. Target ID

20. Missile impact

APPENDIX D

NLOS EUE TASK ILLUMINATION EVALUATION

DEPARTMENT OF THE ARMY
U.S. Army Research Institute for the Behavioral and Social Sciences
Fort Bliss Field Unit, P.O. Box 6057
Fort Bliss, Texas 79906-0057

PERI-SBC (70-n)
26 September 1990

**MEMORANDUM THROUGH DIR, ARI FAAD MANPRINT TASK FORCE (ATTN:
DR DEPONTBRIAND)**

**TO: TRADOC SYSTEM MANAGER - FAAD, ATSA-TSM-F, (ATTN:
MAJ FEDAKO)**

SUBJECT: NLOS EUE TASK ILLUMINATION MANPRINT EVALUATION

1. INTRODUCTION:

a. The present evaluation investigated whether NLOS gunners could perform tasks under conditions of light discipline, whether light attachment points could be identified that would free the gunner's hands, and provided a "quick look" comparison of alternative illumination sources which might be used to reduce the NLOS light signature. Concerns regarding NLOS task illumination requirements were identified in the NLOS Initial Operational Evaluation (IOE) system Force Development Test and Experimentation (FDTE) Test Report, and in follow-on discussions within the NLOS Human Engineering Working Group (HEWG). The use of unfiltered flashlights, chemical light sticks, and other vehicle light sources was not controlled (light discipline) during NLOS FDTE which may have significantly altered the tasks that were performed and influenced task performance time and accuracy. The simple requirement for the crew to hold a flashlight while performing in-cab tasks at times resulted in a "one-armed" crewmember. During the 4 June, 1990, HEWG meeting discussion of these concerns, the desire to explore ways to minimize NLOS light signature was identified as an issue for exploration. The single missile night reload battle drill was chosen to investigate task illumination issues, though no time standard exists for single missile reload itself. Three task illumination issues were examined:

Issue 1. The ability of NLOS gunners to perform night reload tasks under conditions of light discipline using two alternative light sources: the standard issue flashlight with red filter, and a prototype low signature cluster map light (CML) flashlight.

Issue 2. The relative light source Red-Infrared signature of three alternative task light sources: standard issue Army flashlight with a Red Filter, standard Army flashlight with a prototype Blue-Green Filter, and a prototype CML flashlight.

Issue 3. NLOS gunner recommendations for locating light holding fixtures to allow for hands-free task performance at night.

b. The NLOS task illumination concern was chosen for evaluation as part of the NLOS Extended User Employment (EUE) MANPRINT program as a means of demonstrating three key elements of the MANPRINT approach: (1) early and continuous evaluation of soldier issues to influence system design, (2) development and application of new tools, and methods to analyze system performance issues, and (3) refinement of issues and criteria for future evaluations. The NLOS task illumination evaluation was conducted over a period of two days during normal daylight duty hours. Use of commonly available resources allowed the evaluation to be conducted at no cost.

2. METHOD:

a. Overview: On 25 September, 1990, eight single missile reload battle drills were carried out in a simulated night environment in building 5805 at Ft. Bliss, Texas. Half the drills were conducted with Red Filter flashlights, and half were conducted with CML flashlights. While the decision to carry out only eight trials did not allow for statistical comparisons, it should be noted that only two night MOPPO single missile reload battle drills were conducted during the entire course of NLOS FDTE. Two crews of two gunners each carried out four drills. Crew members rotated task duties after each trial. The two NLOS crews performed the single missile reload battle drill tasks identified in BATTLE DRILLS FOR NON-LINE-OF-SIGHT FIBER OPTICS GUIDED MISSILE SYSTEM (NLOS FOG-M) Version 7 (18 May 1989) (Attachment 1). During the reload battle drill a single 147 lb dummy missile was removed from and reloaded onto the NLOS system launcher. The time line for the single missile reload drill was measured from the gunner's command "Prepare for missile reload" until both crewmen completed all tasks and returned to their seats in the crew cab.

b. NLOS Gunner Demographic Data: The evaluation was conducted with NLOS gunners from A Battery, 2nd Battalion, 6 Brigade Air Defense Artillery at Ft. Bliss, Texas.

Crew #1: Gunners 1 and 2

Crew #2: Gunners 3 and 4

Gunner 1: MOS 16R, Height 6'0"

Gunner 2: MOS 16P, Height 5'11"

Gunner 3: MOS 16S, Height 5'8"

Gunner 4: MOS 16R, Height 5'10"

c. Alternative Light Sources Evaluated:

1. Standard issue flashlight with Red Filter

2. Standard issue flashlight with a prototype Blue-Green filter

3. Cluster Map Light flashlight. This light incorporated a number of small light sources producing light in a limited spectrum to achieve its illumination, hence the name "cluster light". This prototype light was somewhat smaller than the standard issue flashlight and the lens head is in-line with the body of the flashlight (see figure 1). In contrast the lens head of the standard issue flashlight is turned 90 degrees from the body of the light. The CML flashlight has an on-off switch with a five-level power setting at its base. The CML flashlight had a mercury switch installed so that in one setting mode the light would come on whenever pointed down.

4. Cluster Map Light "Clip On" light. This prototype light used the multiple limited spectrum light sources principal as does the CML flashlight. The light was housed in a circular tube approximately four inches long and one inch wide, and pivoted within a clip-on mounting bracket (see figure 2). The light was powered through wire connections to the NLOS 24 volt batteries. The CML Clip-On light had an on-off switch with a five-level power setting at its base. Specifications appearing on the light were: Light, Map, Night Vision Compatible, Model LC-CL-3, MFR. TEK-LITE, INC., Union Bridge, MD, 21791. 28 Volt D.C.

d. Video Data Recording Equipment: The primary source of data collection was a Panasonic AG-160 video camera fitted with the Dark Invader Model 3000 night vision system. The Dark Invader has a second generation intensifier imaging tube and provides ultra-low light passive night vision. Typical image tube resolution is 36 line pairs per millimeter across the image tube's 25 millimeter fiber optics viewing screen. Illumination was provided by two 500 watt Infra-red lamps. Illumination was not visible to the naked eye, but was sufficient to fully illuminate the vehicle and reload task performance. Equipment and photo technicians were provided by Ft. Bliss TEXCOM Air Defense Artillery Board Instrumentation Branch, Photo Section.

e. Pre-Test Training: On 24 September, 1990, practice drills were held in building 5805 at Ft. Bliss to familiarize NLOS gunners with night reload tasks. The bay was blacked-out by placing cardboard over three windows. The light level was reduced to a point where no objects were visible at first (couldn't see your hand in front of your face), though some night vision adaptation occurred during each battle drill. Between each battle drill the building bay door was opened to flood the room with bright daylight to reduce any night vision adaptation on the part of test participants.

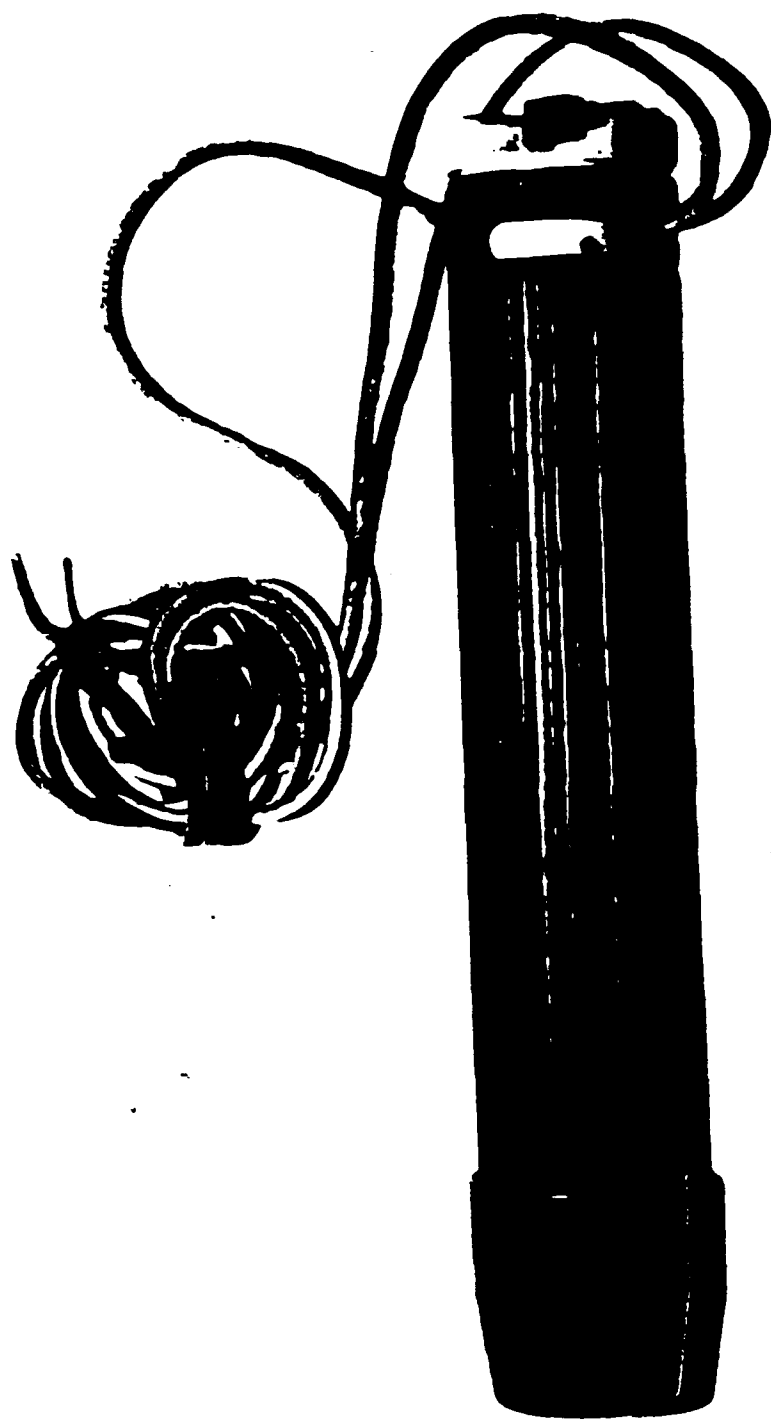


Figure 1. Cluster Map Light flashlight.

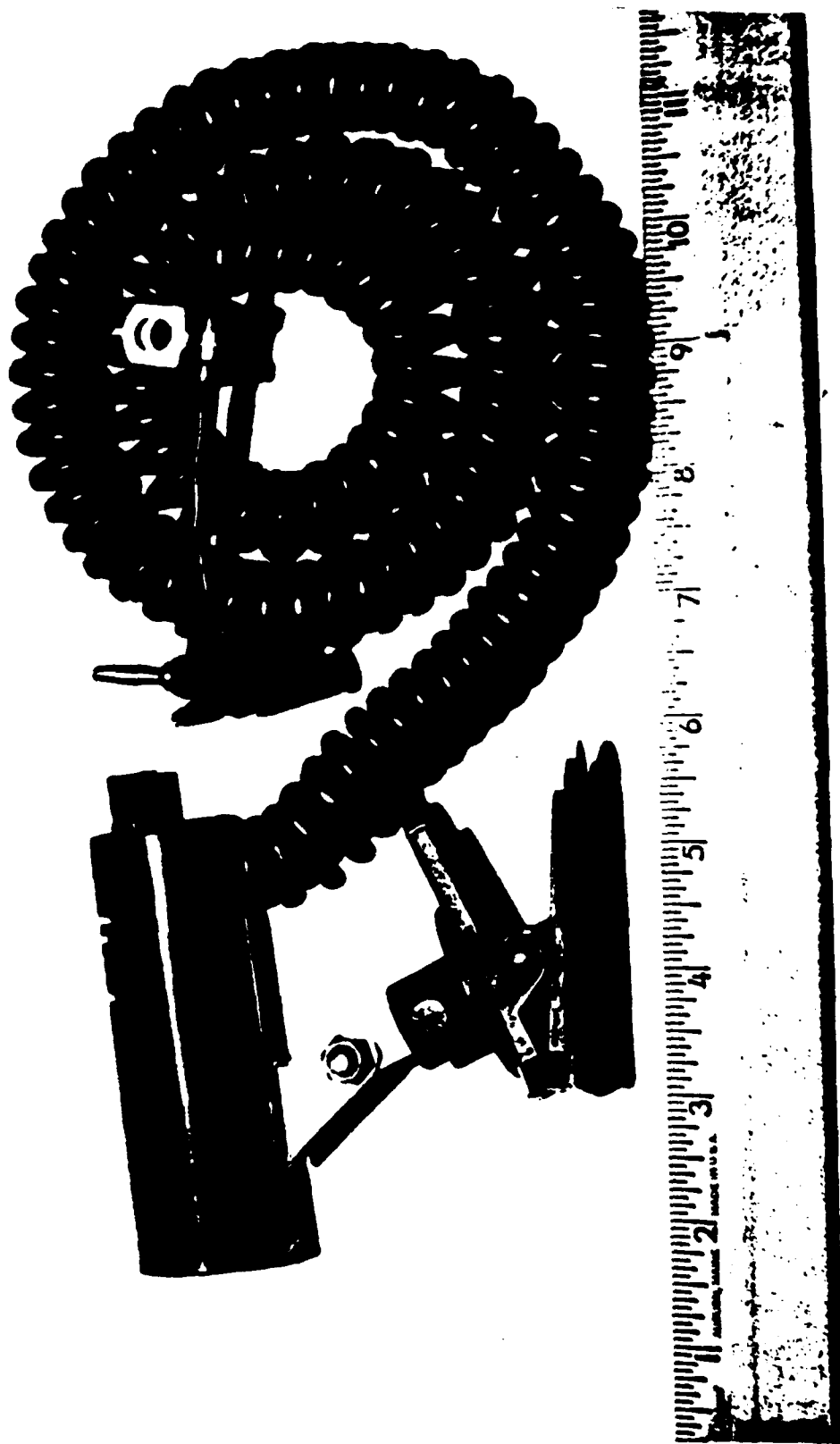


Figure 2. Cluster Map Light "Clip-On" light.

f. Test Conduct:

1. Issue 1: Night Reload Battle Drill Performance Evaluation. To facilitate video recording, the outermost missile canister on the drivers side of the vehicle was the missile removed and installed for all drills except Trial #3. For Trial #3 the outermost missile canister on gunner's side was removed and installed, to present a different task performance perspective to the camera. After the eight trials were completed the NLOS gunners participated in a structured debriefing using the questionnaire in Attachment 2. Order of the drills and lighting conditions were as follows:

Trial #1: Crew #1, GI flashlight (red filter)

Trial #2: Crew #2, GI flashlight (red filter)

Trial #3: Crew #1, Prototype flashlight (cluster light)

Trial #4: Crew #2, Prototype flashlight (cluster light)

Trial #5: Crew #1, GI flashlight (red filter)

Trial #6: Crew #2, GI flashlight (red filter)

Trial #7: Crew #1, Prototype flashlight (cluster light)

Trial #8: Crew #2, Prototype flashlight (cluster light)

2. Issue 2: Light Signature Evaluation: The Red Filter flashlight, a Blue-Green Filter flashlight, and the CML flashlight were placed on the concrete floor at the rear of the vehicle approximately fifty feet from the camera. The three lights were lined up five feet apart, facing the camera, and then turned forty-five degrees off axis, yielding three clearly defined signature images. The signatures were recorded on video tape using a camera with a night vision device attached. Comparing the size of the light images on a twenty-inch diagonal television screen, their relative signature (area of bright glare) was determined.

3. Issue 3: Light Source Location Evaluation: Each crewmember used the Red Filter, Blue-Green filter, and the CML Clip-On and flashlights to read a map in the NLOS crew cab in the blacked out bay. Crewmembers identified where the lights could optimally be placed, and the preferred light level intensity position for the CML Clip-On and CML flashlight. The crewmembers were given copies of a structured interview guide to familiarize themselves with the questions that would be asked at the end of the reload trials. Some data was gathered on cab lighting while the gunners identified optimal placement and illumination levels.

3. RESULTS:

a. Issue 1: Task performance times summary: Battle drill performance times appear in Table 1. The small data set does lend itself to statistical comparisons, however several observations can be made. The crews can perform reload under conditions of light discipline, with both the standard issue Red Filter flashlight and the prototype CML flashlight. The overall mean reload time was 7 minutes and 44 seconds for the eight trials. Team 1 performed the reload drill on the average of 1 minute and 40 seconds quicker, and both teams performed the reload drill about 30 seconds quicker using the standard issue Red Filter flashlight. Performance times for both Red Filter and CML flashlight cannot be compared to any FDTE times, as no record of single missile reload times was presented in the FDTE Test Report. Also, there is no single missile reload performance time standard in the NLOS ROC. Missile canister guide alignment was the one task that caused delays during trials. This task requires lighting for precision alignment of a "U" shaped guide at the front, middle, and rear on the bottom of the 147 lb. missile canister with a one-inch square rail on which the canister rests.

b. Issue 2: Light Signature Comparison: The video taped picture of the Red Filter, Blue-Green filter, and CML flashlight signature images were displayed on a twenty-inch TV and measured so that their relative signature size (area) could be determined. All measurements are approximate as the image sizes were small. The Blue Filter signature was found to be 60.5% of that of the Red Filter signature, and the CML flashlight signature was found to be 11.2% of that of the Red Filter signature.

c. Issue 3: Light source placement: For in-cab tasks, crewmembers recommended placing CML Clip-On lights on the radio rack, one on each side, to provide lap level illumination for driver and gunner. No requirement was identified for a fixture to hold a light source outside of the cab to aid reload tasks. From a review of the video taped trials it was observed that at times crewmembers would simply lay their flashlights down on the vehicle fenders and on top of the canisters in the missile rack to provide task illumination. Crewmembers would also fasten their flashlights on their web gear. Members of crew #1 typically wore the CML flashlight dangling from a cord around their neck. The task of aligning the three missile canister guides with the missile rack support rail was identified as requiring a great deal of lighting to illuminate the fine alignment work, while at the same time requiring heavy lifting to support and maneuver the 147 lb. canister.

4. DISCUSSION

a. Evaluation Issues:

Issue 1. The evaluation revealed that NLOS gunners can perform reload tasks under conditions of light discipline with both the standard Red Filtered flashlight and the prototype low signature CML flashlight. Possible future action: do a full six-pack reload against the ROC performance standard.

Issue 2. Comparison of the illumination signatures of three light sources showed that in comparison to the Red Filter flashlight, a Blue-Green Filter reduced the standard flashlight signature to about 60%. The signature from the CML flashlight was only about 11% of that of the Red Filter flashlight. Possible future action: do a spectrometer evaluation of the alternative light sources to accurately quantify their relative signatures, and redo the video taped recording with a greater magnification camera lens to provide a larger screen image of the light sources.

Issue 3. NLOS gunners recommended adding CML Clip-On lights in the area of the radio rack to allow for lap level illumination for both the gunner and the driver. No light holding fixtures were identified for use in missile reload tasks. Possible future action: can we provide simple brackets on the radio rack where both crewmen can clip on their standard issue flashlights for hands-free illumination of lap top tasks?

b. MANPRINT Process Demonstration: NLOS task illumination was explored as a MANPRINT concern to illustrate the process of follow-on evaluation of lessons learned from testing, identification of inexpensive methods and tools to analyze system performance, and the identification of ways in which to improve future performance testing. The evaluation followed up on unanswered questions from NLOS FDTE, and the findings should have implications for the design of the FSD system reload equipment. The evaluation was conducted in part to show the utility of doing low cost part-task motor pool evaluations. Eight MOPPO night reload drills were conducted during the EUE evaluation compared to only two drills conducted during NLOS FDTE. There was no cost associated with the EUE evaluation as it relied on commonly available facilities and was conducted during normal duty hours. The use of Night Vision equipped video tape equipment allowed the evaluation to be conducted with only one data collector. The emphasis on maintaining night discipline, and measurement of light signature should be incorporated into NLOS FDTE II testing. Inexpensive motor pool night battle drill practice should be conducted prior to going into any major operational test. Don't put off answering simple questions until a big test, sooner is better.

c. Detailed Discussion Of Trial Task Performance

1. Task lighting requirements: Task lighting requirements were identified from a review of the video tape for the eight trials. Soldiers demonstrated that they did not need any light source to remove the brush guard. Light was used during insertion of the reload boom pedestal pin and to find the chain hoist laying on the floor of the building. Light was again used for the task of positioning the chain hoist assembly on the reload boom rail. Light was used in attaching the sling around the canister, and to straighten

out the hoist chain. The requirement for task lighting was particularly important in matching the missile canister guides to the missile rack rails. Lighting was also generally used in detaching, attaching, and inspecting the missile canister cables.

2. Common task difficulties: The task of aligning the "U" shaped guides on the bottom of the missile canister with the supporting rail of the missile rack required the most lighting, appeared to be the most difficult, causing delays and requiring repeated attempts for successful completion. Alignment of the three canister guides with the support rail required that crewmembers repeatedly lift and realign the 147 lb canister to close tolerances. This concern with lighting requirements and fine alignment tasks should have implications for the NLOS Full Scale Development system where one man working on top of the vehicle will align 233 lb. missiles.

3. Observations:

a. Clipping a Red Filter flashlight onto web gear while performing tasks produced a swinging/flashing red beacon like a train crossing signal to the Night Vision equipped camera. May need to emphasize, or introduce as SOP, that crewmen use their flashlights in the "push button for on" mode whenever possible, rather than leaving the light on during task performance.

b. Alignment of the missile canister guides with the supporting missile rack rail was an awkward task requiring the crewman to use one hand to aim the flashlight while lifting and aligning the missile canister with his free arm and shoulder. What are the implications for a 233 lb missile one man on vehicle alignment task.

c. The standard flashlight with Red Filter made critical map information (artillery impact areas) displayed in red disappear. TSM NLOS says that printed red map information should appear under the red filter condition, but that the red information on the map used in the evaluation might have been a local over-stamp which would disappear.

d. With realistic hands-on training crewmen were able to perform NLOS reload tasks such as brush guard removal simply by feel with no illumination at all. This finding reinforces the value of equipment bay night operations training.

e. The NLOS IOE systems Gunner's Console produced a great deal of illumination. Gunner's Console illumination created a glare on the windshield that prevented the gunner from seeing a person standing as close as the front bumper of the vehicle.

f. Night reload appears to have been less dangerous due to the technique where the ground man handing up the hoist would hold his flashlight to illuminate the on-vehicle man's two handed task of putting the hoist dolly on the boom rail. Training


developers might wish to do motor pool night operations evaluations with the FSD system to identify such detailed aspects of task assignment that can promote task performance safety.

g. New reload system tasks might require soldiers to communicate clearly to coordinate fine crane movement adjustments. This could be a concern with one man on the ground operating the crane handle and the other on the vehicle guiding the front of the 233 lb. canister into position at the front of the support frame.

h. A cluster map light may be right for the crew cab and reload tasks because all the tasks are within arms reach. The crewmembers stated that the CML lights will not replace the standard issue flashlight because some tasks require longer light focus and greater illumination.

i. Can we identify a fix for the existing equipment (standard issue flashlight) rather than acquiring high cost, limited utility low signature cluster map light equipment? Is there a way to attach an opaque low signature diffusion filter on the standard issue flashlight to illuminate tasks within hands reach while eliminating the long focus and hot spot created by transparent filters and the flashlight mirror focus distance.

6. The POC for this action is Mr. Bill Sanders, AV978-4491/5297.


WILLIAM SANDERS
Research Psychologist

ATTACHMENT #1: BATTLE DRILLS FOR NON-LINE-OF-SIGHT FIBER OPTICS GUIDED
MISSILE SYSTEM (NLOS FOG-M) VERSION 7 (18 MAY 1989): SINGLE MISSILE RELOAD.

Gunner

1. Commands "Prepare for Missile Reload."
- *2. Dismounts vehicle and installs vehicle chocks at rear wheel on the gunner's side.
3. Removes umbilical brush guard.
4. Removes umbilical, fiber optic connectors and quick disconnect pin.
5. Retrieves MHE and hands to Asst. Gunner.
6. Removes antenna.
7. Remove empty can by hand. If can is full, remove using MHE and sling.
8. Attaches missile sling around missile can, C.G.
9. Align can with launch rail.
10. Pushes missile into launcher.
11. Removes sling, seats missile can.
12. Installs umbilical cable, fiber optic connector, and quick disconnect pin.
14. Stows MHE.
17. Installs umbilical brush guard.
- *18. Removes vehicle chocks from the gunner's side.
20. Announces "Missile Reload Complete."

Assistant Gunner

1. Acknowledges.
- *2. Removes SINGAR's hand set, dismounts vehicle, and installs vehicle chocks at rear wheel on the assistant gunner's side.
3. Assists.
4. Mounts vehicle. unseats missile canister.
5. Assembles MHE.
6. Dismounts vehicle.
7. Assists.
9. Raises missile can level with launcher.
10. Adjusts tension on missile sling.
12. Swings MHE to front of launcher.
13. Mounts top of vehicle.
14. Dismantles MHE.
15. Dismounts vehicle.
16. Installs antenna.
17. Assists with brush guard.
- *18. Removes vehicle chocks from the assistant gunner's side.
19. Installs SINGAR's hand set.

END OF BATTLE DRILL NO. 8

ATTACHMENT #2: LIGHTING INTERVIEW FORM QUESTIONS AND CREWMEMBER RESPONSES

1. Did implementation of any Secure Lighting method degrade your capability to do your job?

Answer: "No problems"

2. Did you experience any problems with any aspect of the man-machine interface? If so, please describe the situation.

Answer: "No problems"

3. Were you able to distinguish color information from all color coded sources (using CML lights) lights, indicators, etc.?

Answer: "Yes"

4. Did operators experience any problems due to not being able to see or read any display, warning label, etc.? If so, describe.

Answer: "No problems"

5. Was there ample lighting to perform operator and maintenance tasks in all work areas? Describe inadequacies.

Answer: "Lighting level was OK, crews could do PMCS"

6. Were all visual alarms (i.e., failure lights, easily detected)? If not describe problems encountered.

Answer: No visual alarms were presented to crews. Crews stated that there would not be a problem seeing visual alarms.

7. Was the meaning of indicator lights/legends, meter values, or labels understandable? If not, describe any difficulties.

Answer: "No problems anticipated"

8. Did you have any problems march ordering or emplacing the system? If so, please describe the problem.

Answer: March Order and Emplacement tasks were not performed

9. Were there any problems experienced with energizing/de-energizing or initializing any equipment item? If so, what problems were there? (Evaluation was limited to power-up, map reading, and reload tasks)

Answer: "No problems"

10. Did the Cluster Map Light (CML) or other light sources provide adequate illumination to enable performance of your tasks?

Answer: "Yes, the CML flashlights and Clip-On lights, and the Red and Blue-Green

filter flashlights all provided enough light to perform tasks"

11. Which switch position (illumination level) did you find most adequate/effective for various tasks?

Answers: Gunner #1 1/2 power, Gunner #2 1/2 power, Gunner #3 3/4 power, Gunner #4 full power)

12. What was the most suitable distance to position the lights to accomplish particular viewing/reading tasks?

Answers: Gunner #1 14", Gunner #2 12", Gunner #3 6", Gunner #4 6"

13. Was the CML or other light sources illumination cone too small or too large?

Answer: Three gunners said they were fine, one said they should be wider)

14. Where did you mount the light while in use? (Be specific) Control Panel - Clothing - handles - cab structure.

Answer: The question is specifically referring to the CML Clip-On light. Gunners stated that CMLs should be located on the radio mount below dash level, with one for the driver and one for the gunner.

15. Where did you mount/stow the light when not being used?

--Was the light cable length satisfactory?

--Was the light cable cumbersome or bothersome?

--Was the PWR hookup point satisfactory?

--Which power hookup method is most acceptable (direct wiring or connect plug)?

Answer: This question was not applicable because the CML Clip-On light was not stowed, and the light cable hook-up was a temporary arrangement using small jumper cables to take power off the vehicle batteries.

16. Was the clip too large or too small?

--Was the spring tension adequate/excessive?

(Tension should be greater, it would slide off in off road use)

--Was utilization capability/manipulation satisfactory?

Answer: Gunners said the clip was the right size, but that spring tension would have to be increased and a rubber lip added to the attachment clip so that it would not shake loose during vehicle movement. Utilization was satisfactory.

17. Was the light effective in illuminating control panels to permit adequate viewing of controls and displays to accomplish all required operations?

Answer: "No problems"

18. Was the light effective for reading/viewing TM's, maps and/or other material?

Answer: All four light sources were considered here. The Red Filter flashlight made red danger zones disappear during a map reading task. The Blue-Green Filter made (blue) water markings disappear. Both CML flashlight and Clip-On light provided accurate color representation during map reading.

19. Was the light used for other purposes? If so describe.

Answer: Light was not used for other purposes.

20. Did the light cause excessive glare? noticeable - disturbing?

Answer: No glare problems with the CML lights, the glare from the Gunner's Console limited forward vision out the windshield so that the gunner couldn't see a man standing at the front bumper.

21. Did the light illumination/methods employed for use interfere with the use of the night vision goggles?

Answer: This was not evaluated.

22. How does use of the illumination provided by the CML compare with alternative illumination methods?

Answer: CML provides softer, less bright, with good color rendition. Gunners said they would like both the CML flashlight and CML Clip-On light.

23. Did you encounter any other difficulties in performing tasks using the light?

Answer: No difficulties were observed.

24. Have you suggestions on how the light/illumination level might be improved?

Answer: Gunners agreed that the mercury switch should be removed. Gunners may not have been aware that the mercury switch feature could be turned off.

Added questions:

25. Design of the CML flashlight

Response: Change the CML flashlight to a standard flashlight configuration by adding the attachment clip and turning the lens head 90 degrees. Take out the mercury switch.

26. Prefer fixed CML versus flashlight

Response: For in the cab and reload tasks the CML Clip-On and flashlight are better because of their lower signature, but the standard flashlight must be retained for other tasks.

27. Need a GI flashlight besides the CML fixed or CML flashlight

Response: Yes, CML is good for tasks at hands-reach, but it will not illuminate more than a few feet. Definitely need a standard flashlight in addition to the CML.